Science 20

MODULE 1

The Changing Earth

Distance Learning

Alberta EDUCATION

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Distance Learning

This document is intended for	
Students	✓
Teachers (Science 20)	✓
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General Public	
Other	

Science 20
Student Module
Module 1
The Changing Earth
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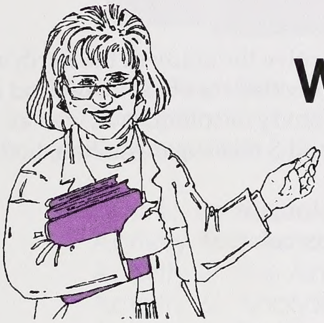
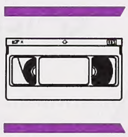


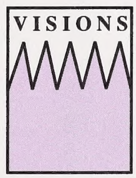
Welcome to Module 1!

We hope you'll enjoy your study of The Changing Earth.

To make your learning a bit easier, watch the referenced videocassettes whenever you see this icon.



When you see this icon, study the appropriate pages in your textbook.

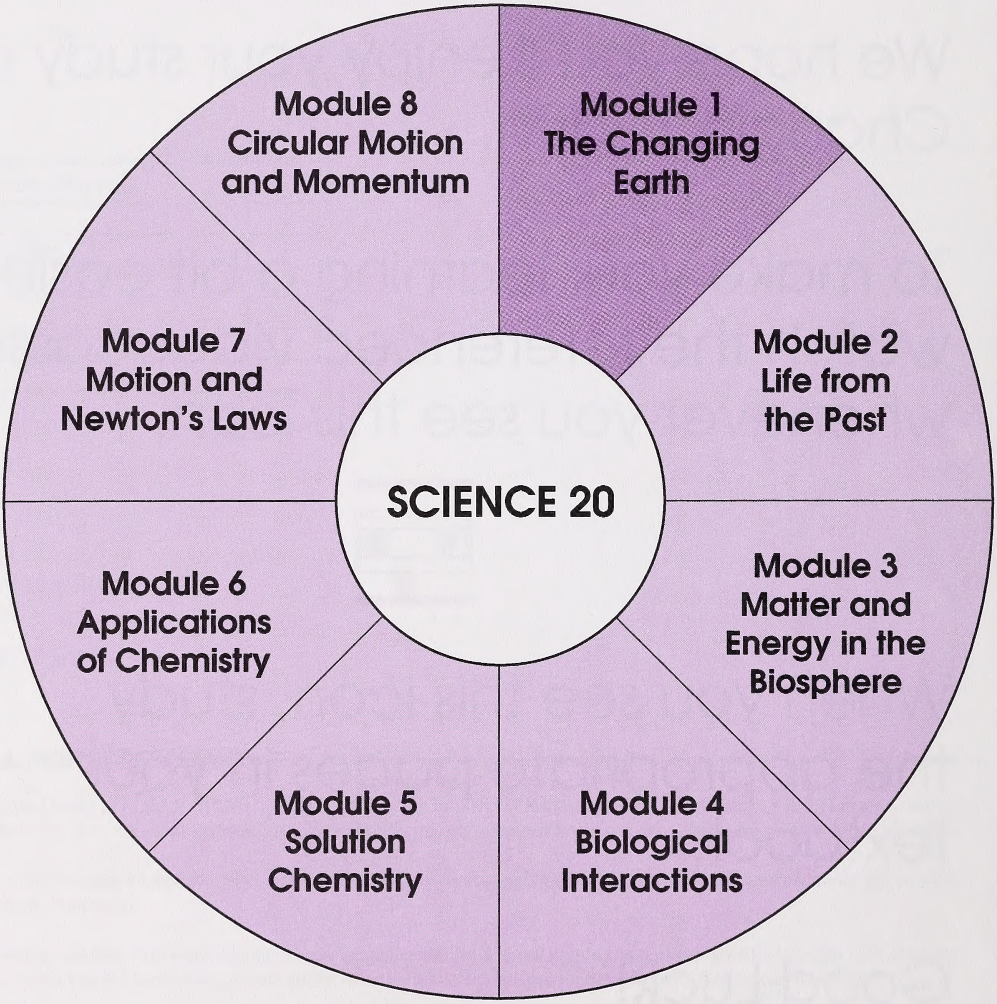


Good Luck!

COURSE OVERVIEW

This course contains eight modules. Modules 1 and 2 involve the study of the Earth's physical features and past life history. Modules 3 and 4 involve the study of life and its interaction with the Earth. Modules 5 and 6 involve the study of solutions as well as how chemistry is used for everyday things. Modules 7 and 8 investigate motion, both on Earth and in space.

The module you are working on is highlighted in a darker colour.



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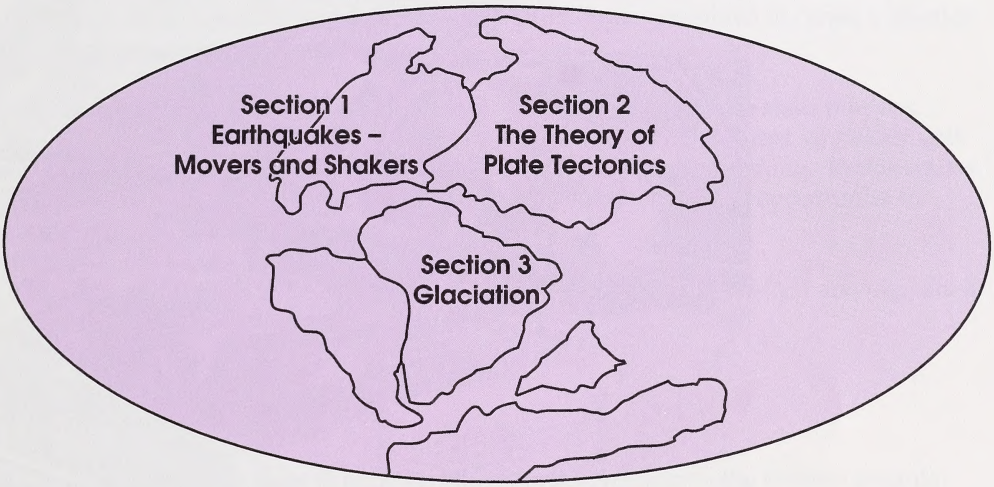
MODULE OVERVIEW

Have you ever taken friends or relatives to see natural wonders? Alberta has its share of natural wonders: the Rocky Mountains, the Cypress Hills, Kananaskis Country, and the Drumheller Badlands. These are great tourist spots that should be around for people to enjoy forever, right?

Not necessarily. Would you believe that almost all of Alberta was buried beneath a kilometre of ice only 15 000 years ago? Or that Alberta was totally covered by an inland sea 85 million years ago? Clearly some tremendous forces must have been at work over the past 85 million years to create the Rocky Mountains and cover them with glacial ice, which, with the help of erosion, carved Alberta's landscape to its present form.

In this module you will be investigating forces that have shaped Alberta and the entire Earth.

Module 1
The Changing Earth



Evaluation

Your mark in this module will be determined by your work in the Assignment Booklet. You must complete all assignments. In this module you are expected to complete three section assignments. The assignment breakdown is as follows:

Section 1 Assignment	35 marks
Section 2 Assignment	32 marks
Section 3 Assignment	33 marks
TOTAL	100 marks

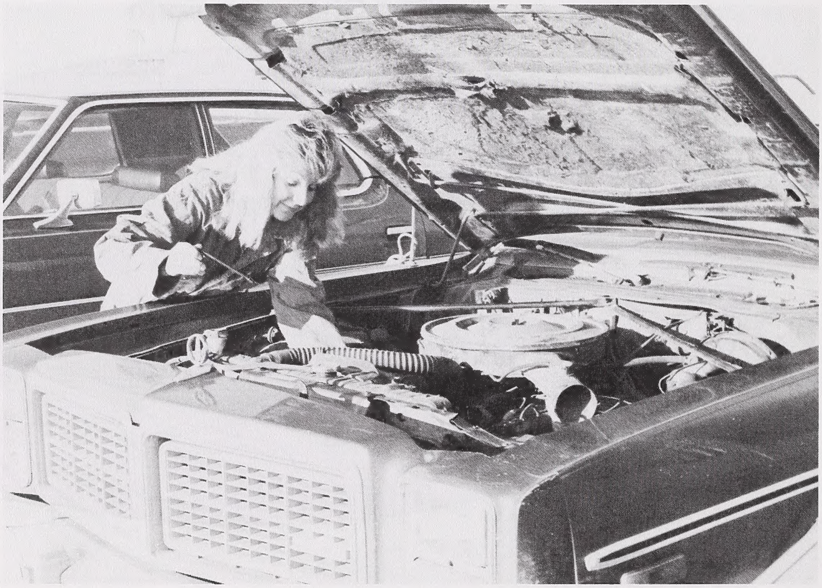
Science Skills

One of the exciting features of this course is that you will develop and improve your ability in the area of science skills. These skills include

- initiating and planning
- collecting and recording
- organizing and communicating
- analysing
- connecting, synthesizing, and integrating
- evaluating the process or outcomes

Although these skills are referred to as science skills, it is important to remember two key ideas.

First, these skills are not just for science. Any time that you solve a problem or make a decision, some combination of these skills will be used.



Therefore, the skills you will develop in this course will be very useful for life-long learning. Nearly every activity of your life will require you to solve a problem or make a decision. Some people would even argue that, in the long run, the skills are more important than the particular topics that you study.

Second, you will be free to use these skills in a variety of ways. It would be wrong to assume that every scientist uses these skills in the same way to solve every problem. Science is very much a human activity, which means individuality and creativity play a large role.

NASA

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The society that the person lives in, the technology that is available, and the very personality of the scientist will determine which skills are combined to create a solution to a problem.

It follows from this idea that the science that you do and the science skills that you prefer to use will be unique to you; and that's okay. It also follows that you likely will not be performing at the same level for all skills, which is a natural thing. In this course you will continually practise all of these skills and you will have an opportunity to assess your level of performance in each skill.

The concept of these science skills will be developed further in Activity 1 and explained in detail in the Appendix for this module.

Important Note

There are no response lines to write on in the questions asked in the student module booklets of this course. This means that you will need to have lined paper handy at all times on which to answer the questions. You will also require your own graph paper. It's probably a good idea if you keep your answer pages in a binder so they are easier to refer to when reviewing. Read all the questions carefully and answer them as completely as possible. Then check your answers in the Appendix. This will allow you to assess your growing abilities in this course.

It is also important that you work through the module activities thoroughly before attempting the questions in the assignments. This will help you to achieve a greater degree of success in your studies.

Section

1 Earthquakes – Movers and Shakers

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Has there ever been an earthquake where you live? Could one occur in the future? How much do scientists really know about what causes earthquakes and where or when they may strike? The previous photograph and news headlines from around the world make it seem that scientists have not been too successful in predicting these catastrophic events. Because earthquakes can be so devastating, scientists have studied them a great deal and have learned much about the forces that shape the Earth's surface.

In Section 1, you will learn much of what scientists have discovered about earthquakes. You will investigate to find out where most earthquakes occur and how they are measured. This section will also introduce technologies used in the study of earthquakes. These technologies have enabled scientists to explore the Earth's interior and discover the sources of energy that are released with such destructive force.

Activity 1: Science Skills

COURTESY OF D. MERRILS

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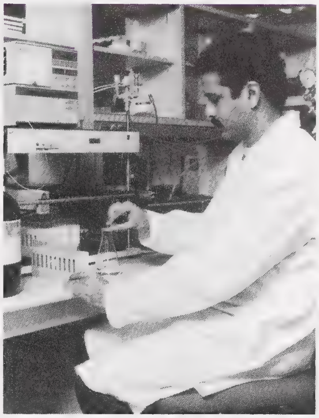


PHOTO SEARCH LTD.

Many people imagine scientists as very brainy people in lab coats doing experiments on mysterious substances. This is not a total picture. Look at the scientists in the three photographs. Yes, they are all scientists! There is a difference in their ages and in the complexity of their investigations but they are all practising science skills. Think about it. The trip to the pond required a lot of planning, some equipment, and transportation. These are skills. The children by the pond probably won't do any sophisticated classification like the students in the lab but they may make some observations and maybe some comparisons. The students in the lab will be making observations and comparisons and will be classifying specimens. They may even collect data over time and write a report of their findings. They may not go as far as to analyse their data or design an apparatus to test a theory – like the research scientist in the last photograph. This would require more time and more skills.

As a student in this course you are a beginning scientist. You may feel a bit short on knowledge and skill but that's why you're here. Throughout this course you will increase both your knowledge and your science skills. You will also keep track of your progress. So what skills will be developed and how are they measured? Some of this work has already been done for you.

Following is a list of science skills developed in this course. A more detailed explanation of each skill is in the Appendix of this module.

Science Skills

A. Initiating and Planning
B. Collecting and Recording
C. Organizing and Communicating
D. Analysing
E. Connecting, Synthesizing, and Integrating
F. Evaluating progress or outcomes

So, do scientists practise these skills all the time? This is a good question. Generally scientists are able to practise any or all of these skills but may only use certain skills in certain situations. As a science student you will do the same. Here's the idea. Look at the three photographs at the beginning of this activity and then answer questions 1 to 3. Take your answers from the list of science skills.

1. What skills are the young people by the pond practising?

2. What skills are being practised by the students in the laboratory?

3. What skills are being performed by the research scientist?

Check your answers by turning to the Appendix, Section 1: Activity 1.

Alright, so you're not a 10-year-old with a pail and a net or a research scientist at the Alberta Research Council. Where do you fit in? In Science 20 that's where! Don't worry if you think some of your skills are rusty. With practice any skill is likely to improve. Skills in this course have levels of improvement that you will experience. Take a look at the science skill levels in the Appendix. Compare level 1 to level 4 under skill A, Initiating and Planning. Notice how the skill level changes. You may already be at skill level 3 in some skills.

Science Skills

- ☑ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

How specific are these skills? Well, can you draw and label a graph? See level 3 in skill C, Organizing and Communicating, in the Appendix.

Science skills are practised in Science 20 in a user-friendly way. Throughout the modules science skills icons, like the one at the left, will tell you when particular skills are applied. These skills will be applied in laboratory investigations, research projects, graphing, setting up charts, and so on. Notice the icon beside question 1 in Activity 2. You will be setting up a chart to organize information. This is skill A – Initiating and Planning. You will also fill in the chart. This is skill C – Organizing and Communicating. In the assignments, another skills icon is used to assess your skill level. Assess? That's right. But there is a difference; both you and a teacher will assess your science skills. Immediately after answering certain assignment questions you will evaluate your skill level in a box like this:

Self:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐
Teacher:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

Here's an example:

Look at question 7 in your assignment booklet for Module 1. Do not try to answer this question at this time. Notice that skills A, C, and E are being assessed. Skill A, Initiating and Planning, is practised because you are planning your own design for the office tower. Skill C, Organizing and Communicating, is practised because you are actually drawing the structure. Skill E, Connecting, Synthesizing, and Integrating, is being practised because you are developing an explanation of the technologies you used in your design. After answering this question, if you felt you drew a good design and it shows the information very well, you might give yourself a 4 for each of skills A and C. If you felt you had some trouble explaining the technology you might give yourself a 2 for skill E. Your assessment box might look like this:

	A.	B.	C.	D.	E.	F.
Self:	4		4		2	
Teacher:						

And when the teacher assessed your science skills, they may have indicated like this:

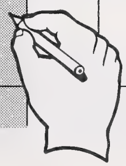
	A.	B.	C.	D.	E.	F.
Self:	4		4		2	
Teacher:	3		4		3	

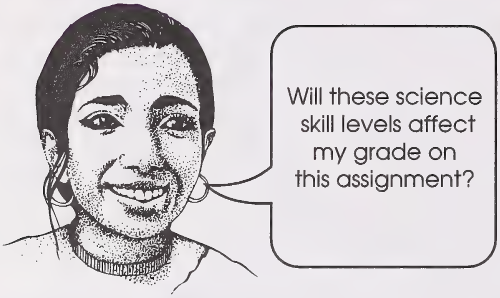
By comparing your assessment to the teacher assessment you can see they are very close. A little improvement could be made in skill A. In skill C you are at level 4 already and both you and the teacher agree on the level you are at. In skill E the teacher felt you did a better job than you did. A good start! The teacher may write you a short note explaining any differences.

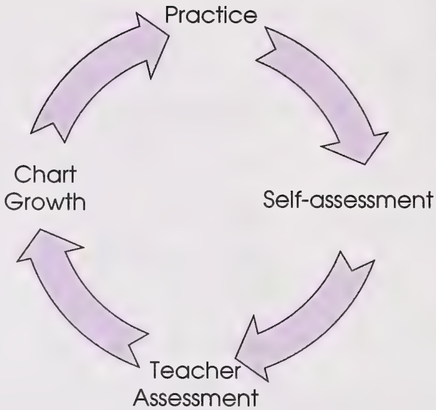
Now you would record both your assessment and the teacher assessment on the Skill Assessment Record in the Appendix of Module 1.

SKILL ASSESSMENT RECORD

Feedback from Assignments			Initiating and Planning		Collecting and Recording		Organizing and Communicating		Analysing		Synthesizing and Integrating		Evaluating	
Module	Section	Question	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher
1	1	7	4	3			4	4			2	3		







It is important for you to realize that this teacher skill level assessment should **not** be interpreted as part of your grade. Rather, it is valuable feedback to help you to know the areas where you need to improve. Everyone can improve their science skills. Now move on to your study of The Changing Earth.

Activity 2: The Anatomy of an Earthquake

For years, dire warnings were issued – "Major Quake Predicted for San Francisco!" "The Big One Is Coming – Scientists Say." "Don't Build Your Home Here!"

People in San Francisco learned to live with the fear that the Earth's surface may suddenly, violently change, bringing destruction, injury, and even death. Then on October 17, 1989, it happened.

If you have access to the video entitled *Living with the Earth, Part 1*, you may view this video on the 1989 San Francisco earthquake. This video will give you an introduction to the power of earthquakes.

VISIONS

Read the introduction to Chapter 1 on page 2 of *Visions 2* to find out about changes to the Earth's surface that occurred on that fateful day. Use this information to answer the following question.

Science Skills

- ☑ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

1. Set up a chart to classify the following as either a sudden change or a gradual change to the Earth's surface; then, add at least three more examples to each list.

   - earthquakes
   - avalanches
   - erosion
   - mountain formation
   - volcanoes
   - soil formation

Check your answers by turning to the Appendix, Section 1: Activity 2.

All of the changes listed in question 1 have something in common – energy! Energy was transformed and resulted in these changes. From previous studies you know that this energy must come from somewhere. The following photographs show both gradual and sudden changes. Where does the energy for these changes come from?

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Sources of Energy

VISIONS

Read Section 1.1 on pages 3 and 4 of your textbook to discover what scientists believe to be the Earth's sources of energy. Use this information to answer question 2.

2. a. Explain the energy conversion that causes changes to the Earth's surface. Be sure to mention the form of the input energy and the output energy.

   b. Give three examples of changes that this release of energy can bring about on the Earth's surface.

Check your answers by turning to the Appendix, Section 1: Activity 2.

What do you know about waves? Waves come in all sizes, they splash in your face when you swim, they make you bob up and down in the water, and so on. You can make waves by simply kicking your feet as you swim, pushing on the oars of a rowboat, or just throwing a rock into the water. Anyway, waves can be fun at times or frightening and destructive.

COURTESY OF GEORGE MUDRYK

Energy Moves in Waves

Scientists believe that all energy waves have the same form and properties. Therefore, a closer examination of any wave should help you to understand the energy waves that are involved in earthquakes. Study the following photograph; then do question 3.

COURTESY OF DAVE BELL

3. Imagine you are in the dinghy. Describe the motion you would feel while riding the waves.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

4. Fill a bathtub with about 10 cm of water and place an empty container (like an old margarine tub) on the water; then make some waves in the water. Describe the motion of the container.

Check your answers by turning to the Appendix, Section 1: Activity 2.

VISIONS

Read the section entitled Many Forms of Energy Move in Waves on page 4 of your textbook to help you answer the next question.

5. What are the two forms of motion of a water wave? How do they compare to the motion of a **seismic wave**?

seismic wave – a shock wave produced by vibrations

Check your answers by turning to the Appendix, Section 1: Activity 2.

Investigation: Investigating Wave Motion

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Complete Activity 1.1 on pages 4 to 6 of *Visions 2*. Read through the entire activity before you begin. If you are working alone, note the modifications in the Procedure section of this investigation.

VISIONS

Purpose

6. State the purpose of the investigation.

Materials

The materials are listed in your textbook. If you are working alone, additional materials are as follows:

- two chairs
- table
- string or elastic bands

Procedure

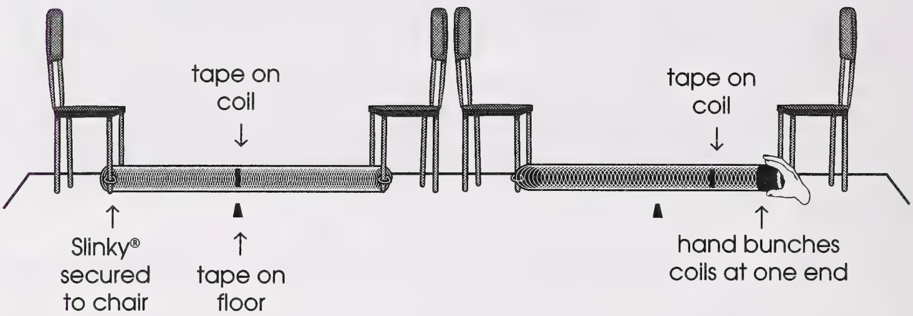
- If you are working in a group, follow the Procedure section on pages 5 and 6 of your textbook; then go to the Observations section of this investigation.
- If you are working alone, you will need to modify the procedure in your textbook.
- Use the following diagrams to help you plan your modifications.

Diagram Showing Possible Modifications to Procedures A and B.

Part A

1. to place tape

2. to time



Note: If you do not have a smooth floor, use a tabletop and place the backs of the chairs up to each end of the table.

Part B

Same sort of set up as in Part A 1.

7. Write out the steps you will follow to complete this investigation. (Answer this question only if you are modifying the procedure.)
8. List three variables you will need to control for each part of the investigation.
9. Predict what you will observe for Parts A and B. Give reasons for your predictions.

Observations

10. Read questions 2 to 4 in the Observations section on page 6 of your textbook. Base your observations on these questions. Design a chart for your observations. (Remember you may wish to repeat each procedure to get a more accurate result.)

11. Carry out your investigation and record your observations.

Analysis and Interpretation

12. Do questions 1 to 3 in the Analysis and Interpretation section on page 6 of *Visions 2*.

Check your answers by turning to the Appendix, Section 1: Activity 2.

The Energy of an Earthquake Moves in Waves

VISIONS

Read the bottom of page 6 of your textbook to help you understand the wave motion of the Slinky® in Activity 1.1. Use this information to answer the next question.

13. Use the terms **longitudinal wave** and **transverse wave** to describe the wave motion of the Slinky® in Parts A and B of the previous investigation. Include a diagram to illustrate your description.

longitudinal wave – an energy wave in which the particles of matter vibrate parallel to the direction of energy propagation

transverse wave – an energy wave in which the particles of matter vibrate perpendicular to the direction of energy propagation

elastic rebound – the ability of a material to return to its original shape after stess has been applied

To discover what effect transverse and longitudinal waves have on the surface of the Earth, read page 7 of your textbook and study Figures 1.3 and 1.4. This information should help you answer questions 14 and 15.

14. Describe why the house in Figure 1.3 may collapse when the shock waves reach it. Use the following terms in your description.

- expansion
- compression
- kinetic energy
- seismic waves
- earthquake
- transverse waves
- longitudinal waves

15. Explain why **elastic rebound** is a good way to describe the modern theory of earthquakes. You may find the analogy of breaking wood shown in Figure 1.4 helpful to include in your explanation.

Check your answers by turning to the Appendix, Section 1: Activity 2.

In Activity 1 you learned that rock layers making up the Earth's crust can break and move suddenly to relieve stress buildup caused by forces within the Earth. When this occurs, some of the released energy travels through the Earth's crust and along its surface in the form of seismic waves. Scientists have developed instruments capable of recording seismic activity. The next activity will examine the design of these devices and the usefulness of the data they generate.

Activity 3: Analysis of an Earthquake

Have you ever thrown a rock into a pond and watched the ripples that formed?

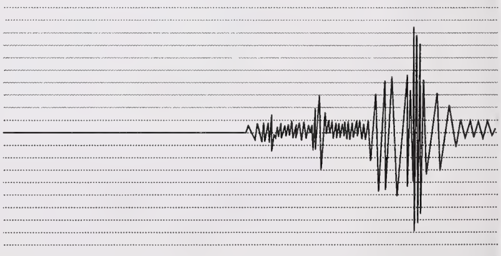
PHOTO SEARCH LTD.

Just as a rock thrown into a pond creates ripples from its point of entry, so too do earthquake waves originate at a certain point and move outwards in all directions.

earthquake magnitude – the amount of energy released at the point of origin of an earthquake

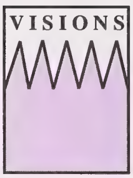
Earthquake magnitude is determined by the amount of energy released just as the size of the ripples on the pond are determined by the size of the rock thrown.

In this Activity you will learn about the devices used by scientists to record seismic activity. You will investigate to discover how scientists make use of seismic data to determine the location and magnitude of an earthquake.



Seismogram

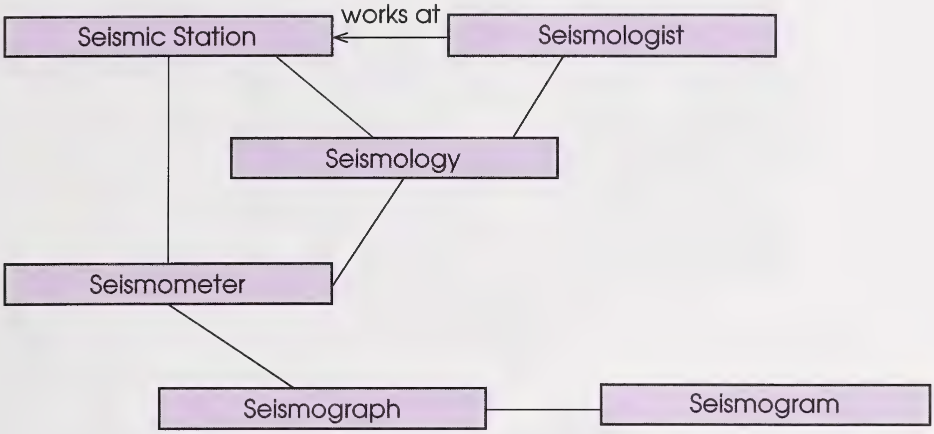
Terms Associated with the Study of Earthquakes



Read pages 8 to 10 of *Visions 2* to become familiar with a number of key terms used for describing and studying earthquakes. Study Figure 1.5. Use the information gained to answer questions 1 to 4.

Science Skills
- ☐ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

1. Draw a web like the one that follows and write appropriate descriptive words on the connecting lines to show the relationships between the terms. Add arrowheads to show the direction of the relation. The first one is done as an example for you.



2. Use the following three terms in a sentence to illustrate how they are related.

   - **focus**
   - **epicentre**
   - earthquake

focus – the point of origin of an earthquake

epicentre – the point on the Earth's surface directly above the focus of the earthquake

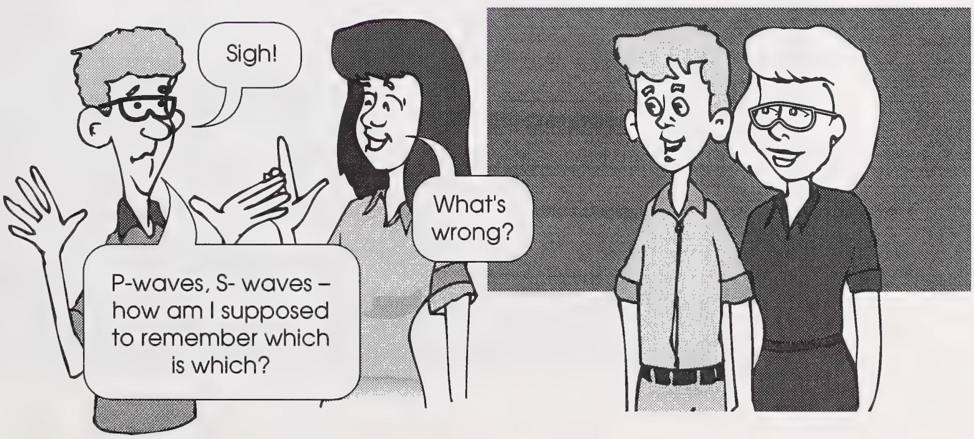
P-waves – the first seismic waves to reach a seismic station (longitudinal waves)

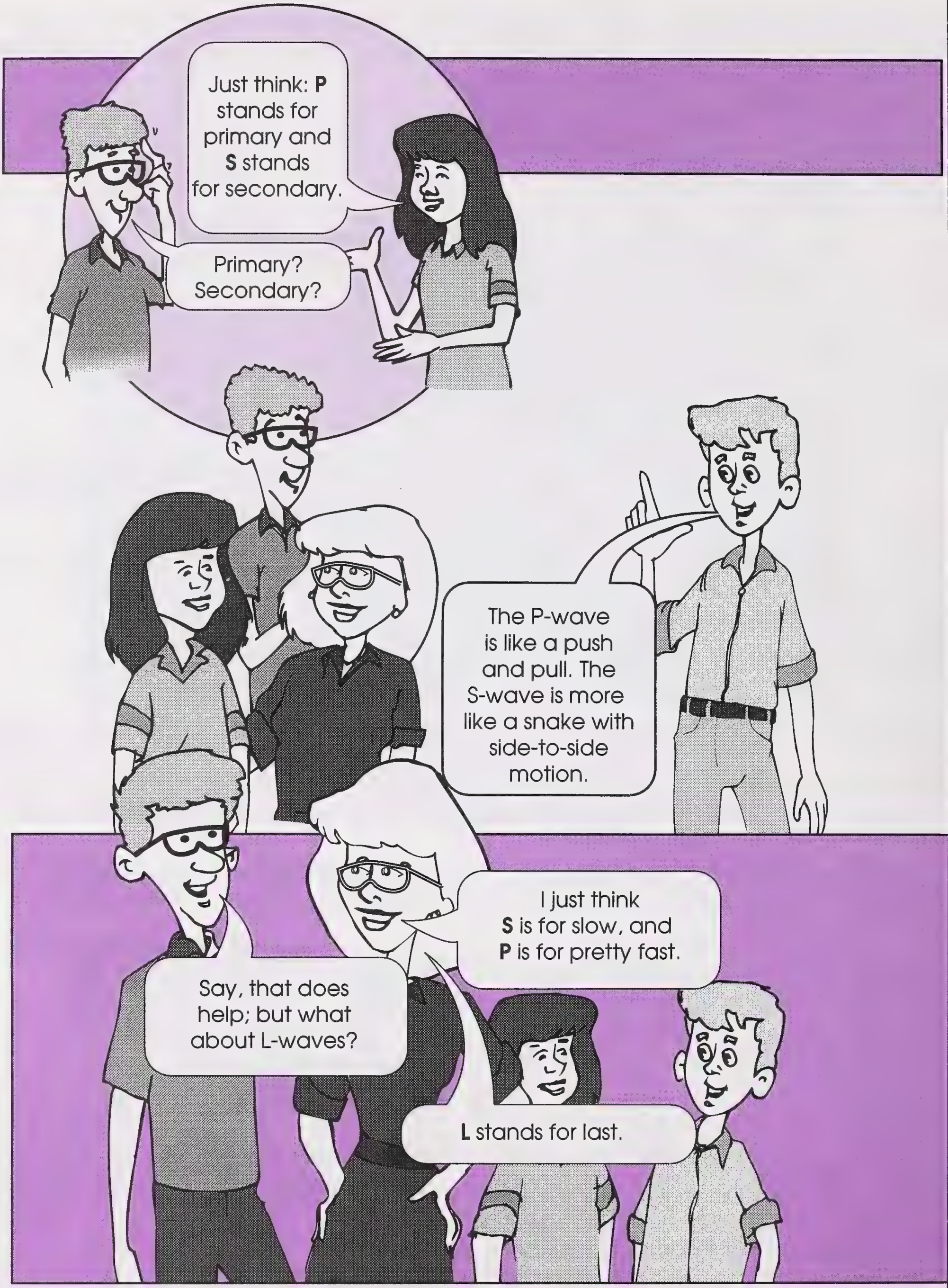
S-waves – transverse, seismic waves arriving at seismic stations after the P-waves

L-waves – surface seismic waves that arrive at a seismic station last

Check your answers by turning to the Appendix, Section 1: Activity 3.

Follow the conversation of the following cartoon characters as they discuss ways of remembering **P-waves**, **S-waves**, and **L-waves**.



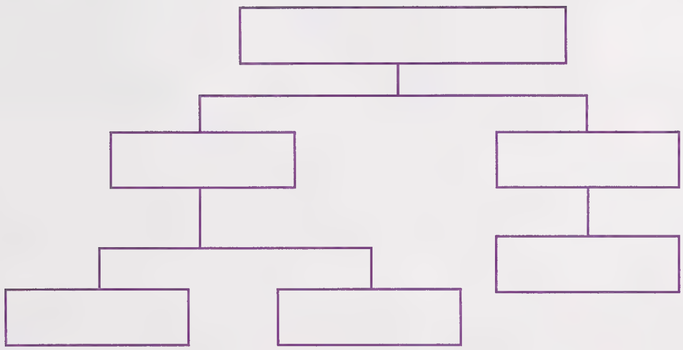

Just think: **P** stands for primary and **S** stands for secondary.
Primary? Secondary?
The P-wave is like a push and pull. The S-wave is more like a snake with side-to-side motion.
I just think **S** is for slow, and **P** is for pretty fast.
Say, that does help; but what about L-waves?
L stands for last.

3. Draw a classification diagram like the one that follows; then place the following terms into the appropriate spot.

body waves – seismic waves that travel through the interior of the Earth

surface waves – seismic waves that travel along the surface of the Earth

- P-waves
- S-waves
- L-waves
- **body waves**
- **surface waves**
- seismic waves



4. Classify P-waves and S-waves as transverse or longitudinal. Justify your classifications.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Understanding the Technology Used to Monitor Earthquakes

VISIONS

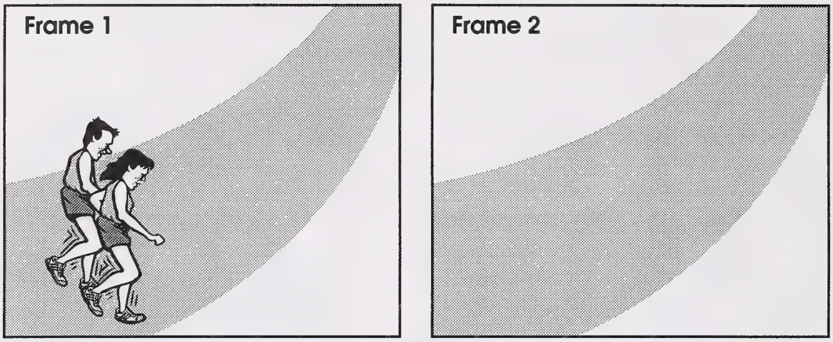
Study page 9 of your textbook to learn more about the technology used to monitor and record seismic activity. Use the information to help you answer questions 5 and 6.

5. Why is it necessary to have more than one seismograph at each seismic station?

6. What role does the principle of **inertia** play in the operation of a seismograph?

inertia – the tendency of a body at rest to remain at rest and a body in motion to remain in motion

7. Look at the diagram of the runners. If the female runner in the first frame can run 1 m/s faster than the male runner, what would the race look like after ten seconds? Draw a diagram similar to the one which follows and use Frame 2 to illustrate the runners positions later in the race.



P- and S-waves are like the runners in the previous diagram. P-waves travel faster than S-waves. Therefore, P-waves will always arrive at a seismic station before S-waves no matter how far the seismic station is from the source of the earthquake. What will be different is the arrival times between P- and S-waves? The difference can be calculated by subtracting the time of arrival of the P-waves from the time of arrival of the S-waves.

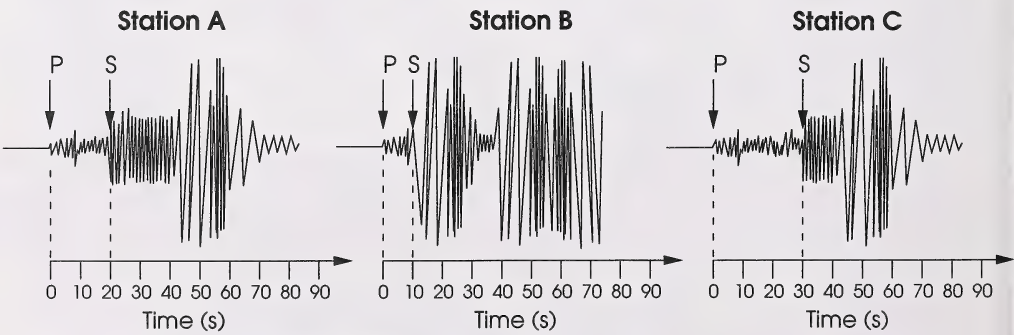


FIGURE 1.1 Diagram of Three Seismograms

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

8. Figure 1.1 shows three seismograms showing different arrival times for S- and P-waves. The scale is set so that the arrival times for the P-waves is zero for each station since it is the difference in arrival times that is important. Calculate the difference in arrival times, and decide which seismogram is located at the seismic station farthest from the earthquake. Justify your decision.

Years of collecting seismic data has made it possible for scientists to develop a table equating the difference between S- and P-wave arrival (in seconds) to distance (in kilometres).

9. Make a chart similar to the one that follows. Complete the chart using the information in Figure 1.1 and Table E.1 in Appendix E on page 553 of your textbook.

Seismic Station	S – P (s)	Distance from Epicentre (km)
A		
B		
C		

The following information illustrates how the distances from question 9 can be used to determine the location of the earthquake on a map. Study the procedure outlined carefully; then answer question 10.

Procedure for Determining the Location of an Earthquake Using Seismic Data

Step 1: Use the scale indicated on the map to convert kilometres (km) to centimetres (cm).

For example, if the map scale is 1 cm = 75 km (as shown in Step 2), then your distances for this earthquake would be as follows:

Seismic Station	S – P (s)	Distance from Epicentre (km)	Distance on Map (cm)
A	20	170	2.3
B	10	86	1.1
C	30	256	3.4

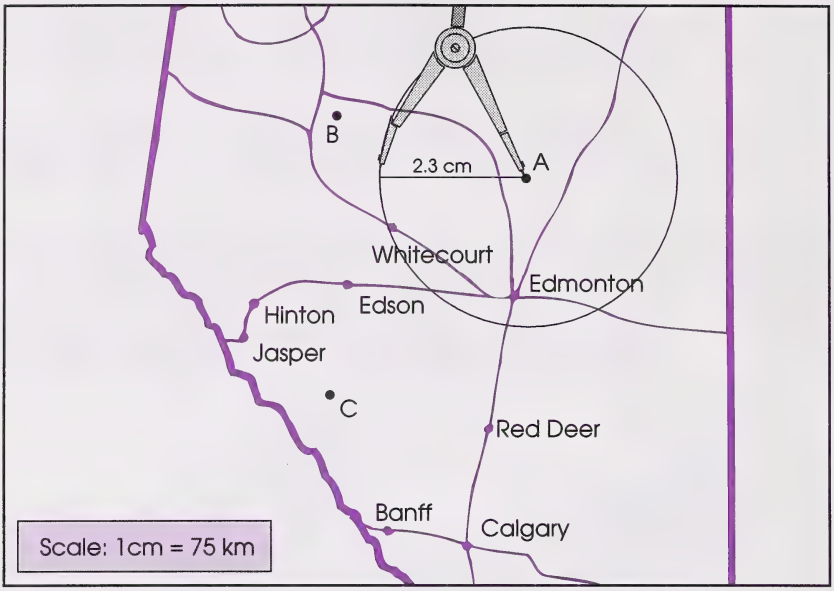
Scale calculation for Station A is provided as an example.

$$\frac{1\text{ cm}}{x} = \frac{75\text{ km}}{170\text{ km}}$$

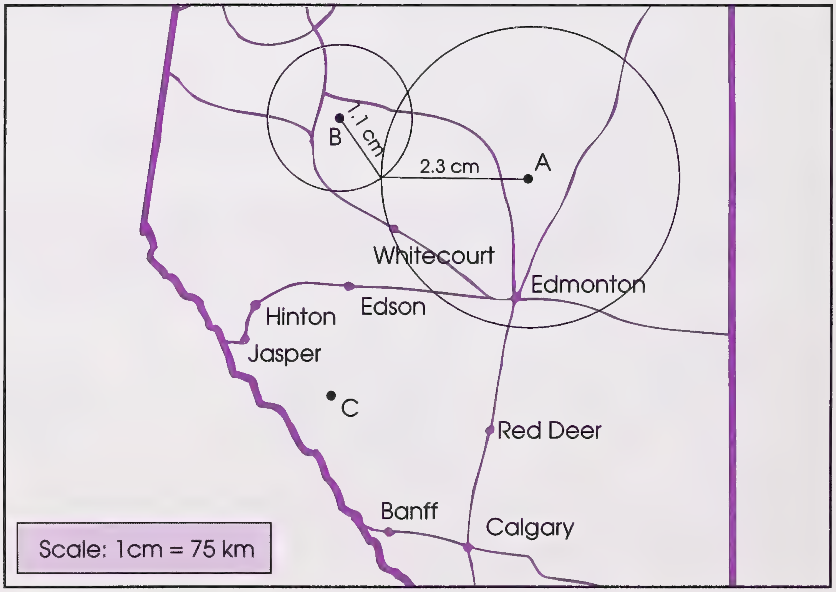
$$x = \frac{1\text{ cm} \times 170\,\cancel{\text{km}}}{75\,\cancel{\text{km}}}$$

$$= 2.3\text{ cm} \quad \text{(2 significant digits)}$$

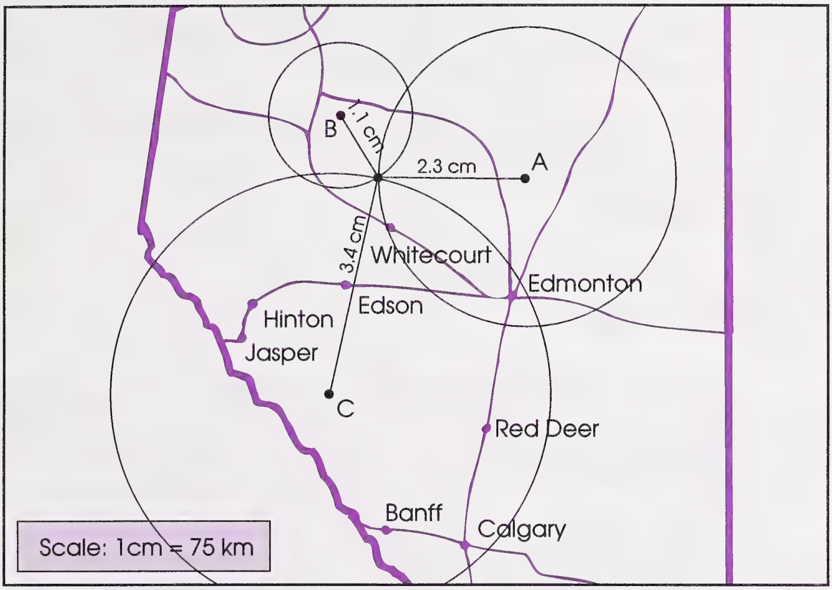
Step 2: Set your compass to draw a circle with a radius of 2.3 cm from Station A.



Step 3: Set your compass to draw a circle with a radius of 1.1 cm from Station B.



Step 4: Set your compass to draw a circle with a radius of 3.4 cm from Station C.



Use the diagrams and the procedure outlined for determining the epicentre of an earthquake to help you answer question 10.

10. Explain why it is necessary to have data from at least three seismic stations to determine the epicentre of an earthquake.

Check your answers by turning to the Appendix, Section 1: Activity 3.

VISIONS

Read the introduction to Activity 1.2 on pages 10 to 12 of your textbook; then answer questions 11 and 12.

11. What factors determine the magnitude of an earthquake on the Richter scale?

12. Explain the difference between an earthquake that measures 4.5 on the Richter scale to one that measures 6.5.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Investigation: Interpreting Data from Earthquakes

Follow the directions of this investigation carefully. Pay special attention to the required components and applied science skills.

Use what you have learned about analysing seismic data to help you complete Activity 1.2 on pages 10 to 14 of your textbook.

Purpose

13. State the purpose of this investigation.

Materials

- map of Alberta (provided in Appendix)
- compass
- ruler
- pencil

Procedure

Read Activity 1.2 on pages 10 to 14 of your textbook carefully and follow the procedure given. Pay special attention to number 4 in the Procedure section. (You may find it helpful to look back through questions 8 to 10 of this activity.) Use Table 1.2 on page 12, and Figure 1.7 on page 13 of your textbook to collect your data. Determine the magnitude relative to each city using a ruler and the scales in Figure 1.7. Do not mark in your textbook.

Observations

14. Make and complete the following charts. Round to the nearest second to use Table E.1.

a.

Station	Difference in S- and P-waves (s)	Distance from Epicentre (km)
Dawson Creek		
Fort McMurray		
Edmonton		

b.

Station	Distance on Map (cm)	Magnitude (nearest tenth)
Dawson Creek		
Fort McMurray		
Edmonton		

c. Determine the average magnitude (to the nearest tenth).

d. Determine the epicentre on the map of Alberta provided in the Appendix of this module.

Analysis and Interpretation

15. Do questions 2 to 4 on page 14 of your textbook. (Note: For question 4, use the formula $t = \frac{d}{v}$ and remember to subtract 8 h to change to Mountain Standard Time.)

16. Conclude your investigation by summarizing how the location and the magnitude of an earthquake can be determined from seismic data.

Check your answers by turning to the Appendix, Section 1: Activity 3.

This activity illustrated how seismic data helps scientists learn about earthquakes. The next activity will examine some of the ways scientists have applied this knowledge to develop technology that reduces the risk of living in an earthquake zone.

Activity 4: Earthquake Technology

In Activities 2 and 3, you learned how seismograms can be used to determine the location and magnitude of an earthquake. This type of information, though important, does not do much to ease the mind of someone living in an earthquake zone. If you live in an earthquake zone, you may be less concerned with the statistics of the last earthquake and more concerned with your safety when the next earthquake strikes.

Predicting Earthquakes

Read the Careers in Seismology feature on pages 26 and 27 of your textbook; then answer the following questions.

1. Dr. Garry Rogers seems to feel that his work as a seismologist has more to do with lowering seismic risk than predicting earthquakes.

   a. What does he mean by *seismic risk*?

   b. How can the seismic risk of an area be reduced?

2. Explain how the work of seismologists can affect society's decisions?

Check your answers by turning to the Appendix, Section 1: Activity 4.

Figure 1.2 shows you how successful scientists are at locating earthquakes.

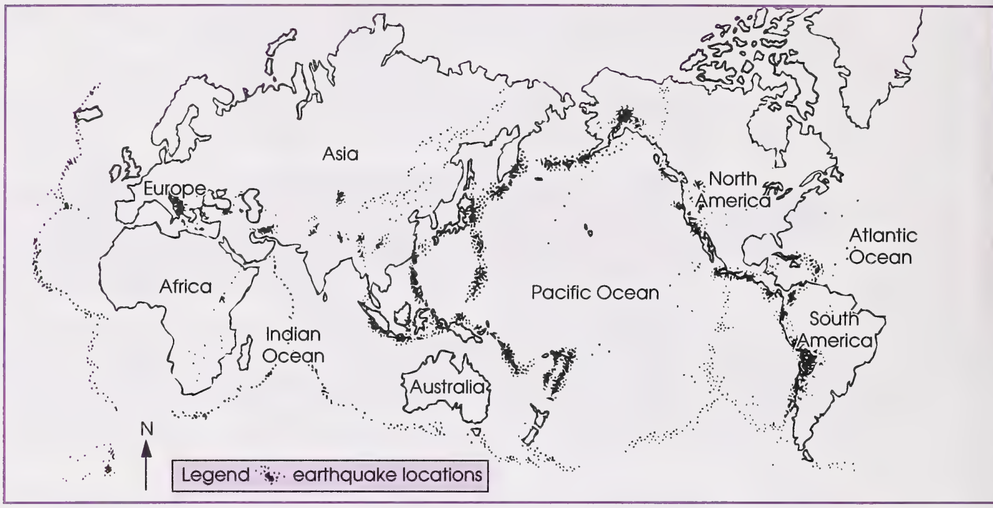


FIGURE 1.2 Earthquake Locations

VISIONS

Figure 1.13 on page 27 of your textbook shows the earthquakes which have occurred in Canada.

To get a better understanding of how successful scientists are at predicting an earthquake, read pages 28 and 29 of your textbook. Use the information to answer questions 3 and 4.

3. There are three variables involved in predicting earthquakes as given on page 28 of your textbook.

   a. What are the three variables?

   b. Which of these variables poses the greatest problem to seismologists? Explain.

4. How accurate do scientists think they can predict earthquakes?

Check your answers by turning to the Appendix, Section 1: Activity 4.

Effects of Earthquakes on Buildings

As you may have seen in pictures or on television, earthquakes can have devastating effects on buildings. The following investigation will help you understand the effects of seismic waves on the ground and in turn on buildings resting on the ground.

Science Skills

- ❑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ❑ F. Evaluating

VISIONS

Investigation: Simulating Surface Motion

Follow the directions of this investigation carefully. Pay special attention to required components and applied science skills.

Read Activity 1.4 on pages 29 to 31 of your textbook.

Purpose

5. Reread the introductory paragraph for Activity 1.4 on page 29; then state the purpose of the investigation.

Background Information

- If you are not in a classroom, you will need to find someone to help you with this investigation.
- If you cannot find anyone to help you with the investigation, you can modify the procedure as illustrated in the procedure part which follows.
- Any permanent marker can be substituted for the overhead marker.
- You can use whatever colour of markers you have available.
- If you have two half sheets of acetate, cut each piece in half only. You want four pieces about 10 cm by 10 cm.

Materials

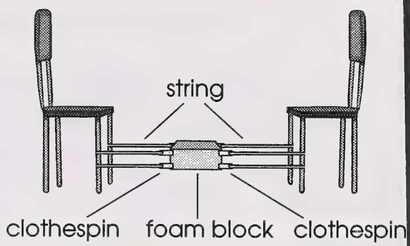
Use the materials listed in Activity 1.4 on page 29 of your textbook. If you purchased a lab kit, your foam block measures 30 cm by 10 cm by 5 cm.

Procedure

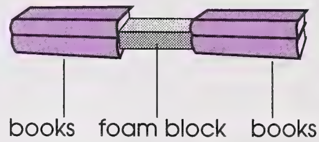
If you are working with someone, follow the Procedure section on pages 29 and 30 of your textbook carefully. Then complete the Observation and the Analysis and Interpretation sections in this investigation.

If you are working alone, you will need to modify the procedure for this investigation. Steps 1 and 2 are the same as in Activity 1.4 in your textbook. The following diagrams show the modifications required for Steps 3 to 5 to complete this investigation.

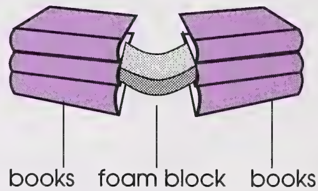
Step 3: Use two chairs, string, and clothespins to hold and stretch the foam block. Follow the rest of Step 3 in your textbook.



Step 4: Use four heavy books or blocks to push the foam together slightly. Follow the rest of Step 4 in your textbook.



Step 5: Use six heavy books or blocks to hold the foam in a U-shape as shown in the diagram. Follow the rest of Step 5 in your textbook.



Observations

6. Predict what you will observe for Steps 3, 4, and 5 in the Procedure.

7. Design a chart for this investigation. Carry out the investigation and complete your chart. Answer Observation questions 1 to 3 on page 30 of *Visions 2* as you complete your chart.

Analysis and Interpretation

8. Answer questions 1 to 4 in the Analysis and Interpretation section on pages 30 and 31 of your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 4.

Protecting Structures Against Earthquakes

9. Study the following photograph carefully. Would it be safe inside or around the building during an earthquake? Explain.

COURTESY OF GEORGE MUDRYK

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

10. How would you change the structure in the previous photograph so that it can still serve the same purpose, but be more earthquake-resistant?

Check your answers by turning to the Appendix, Section 1: Activity 4.

VISIONS

To find out more about how ground movement during an earthquake can affect structures, read pages 31 to 33 of your textbook. Use the information to answer questions 11 to 15.

11. What type of ground movement caused by earthquakes is of greatest interest to structural engineers? Explain.

12. How can wind amplify the effect of an earthquake on a structure?

13. Name two factors that help determine a building's ability to withstand damage during an earthquake.

14. What is *liquefaction*, and how does it affect structures during an earthquake?

15. Describe three techniques structural engineers have developed to make structures more earthquake-resistant.

Check your answers by turning to the Appendix, Section 1: Activity 4.

Activity 4 has examined some of the technology being developed to reduce seismic risk for people living in earthquake zones. Activity 5 will show you what scientists have learned about the Earth's interior as they search to understand why earthquakes happen.

Activity 5: Examining the Earth's Interior

Previously, you learned that earthquakes result when energy is released by the breaking of rock layers stressed beyond their elastic limit. What causes the stress? Where do the forces that compress, stretch, bend, and break rock layers come from? Scientists knew they must look inside the Earth to find the answers.

What Scientists Know About the Interior of the Earth

VISIONS

Read pages 14 and 15 of *Visions 2* to find out what scientists have discovered about the Earth's interior. Use this information to help you answer the following question.

Science Skills

- ❒ A. Initiating
- ❒ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ❒ E. Synthesizing
- ❒ F. Evaluating

asthenosphere – a partially molten layer of the Earth's upper mantle (100 km to 250 km deep)

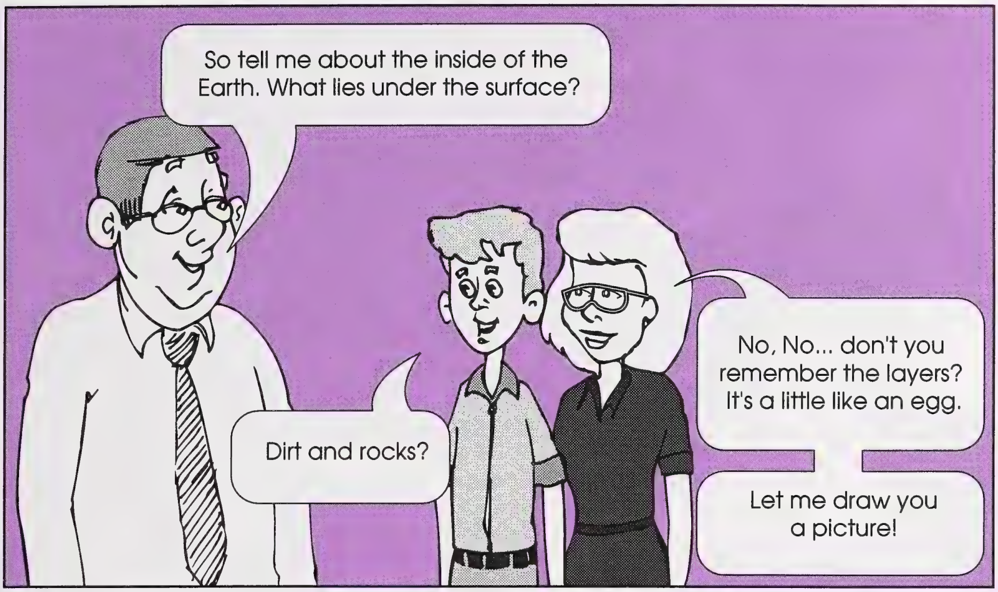
Moho – the boundary between the Earth's crust and upper mantle

1. Arrange the following discoveries into their correct chronological order by placing numbers 1 to 4 in the left-hand column. In the right-hand column, explain what each discovery revealed about the nature of the Earth's interior.

Order	Discovery	Structure of the Earth's Interior
	• prediction of the existence of the **asthenosphere**	
	• discovery of a shadow zone within the Earth	
	• proposition of a theory that divided the Earth's core into two zones	
	• discovery of the **Moho** boundary	

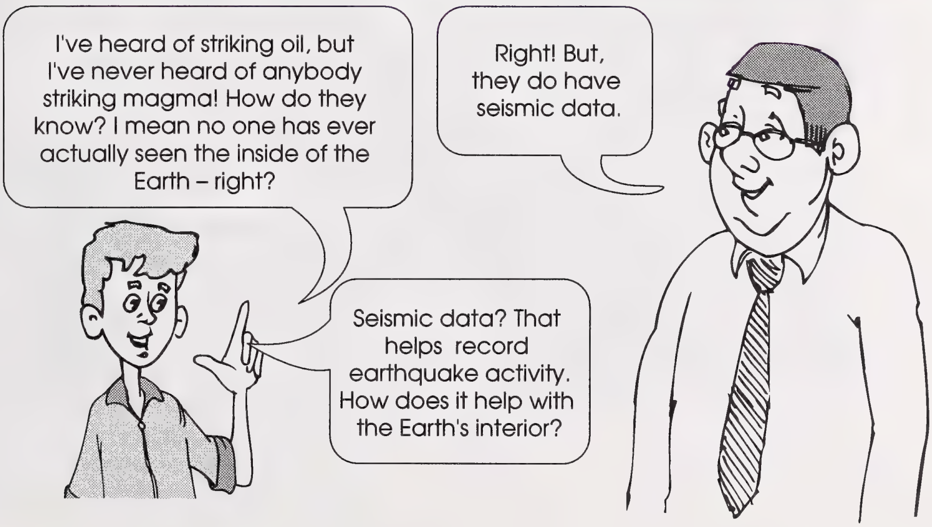
Check your answers by turning to the Appendix, Section 1: Activity 5.

Read the following cartoon, and answer questions 2 to 4.

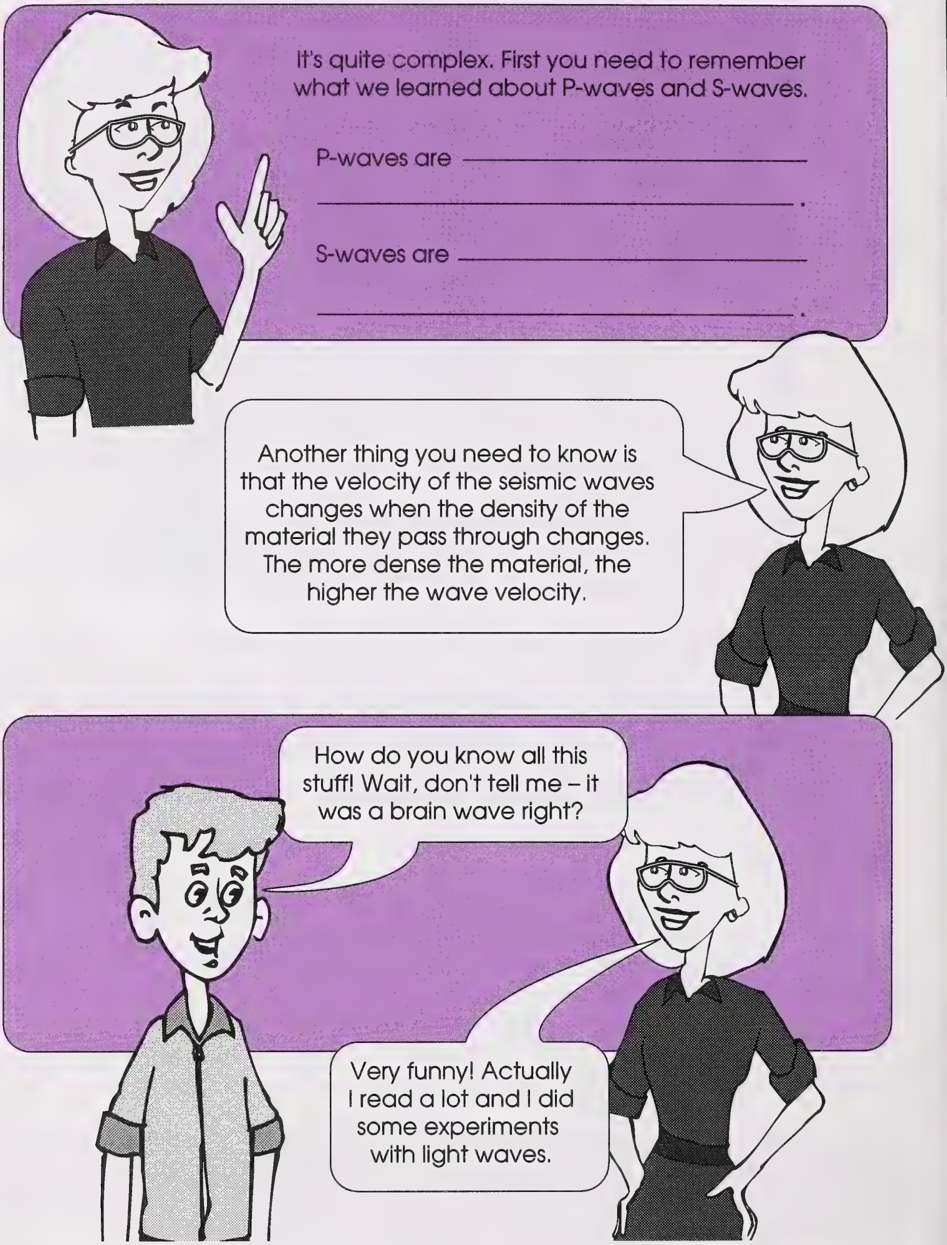


2. Draw a diagram showing the layers of the Earth.

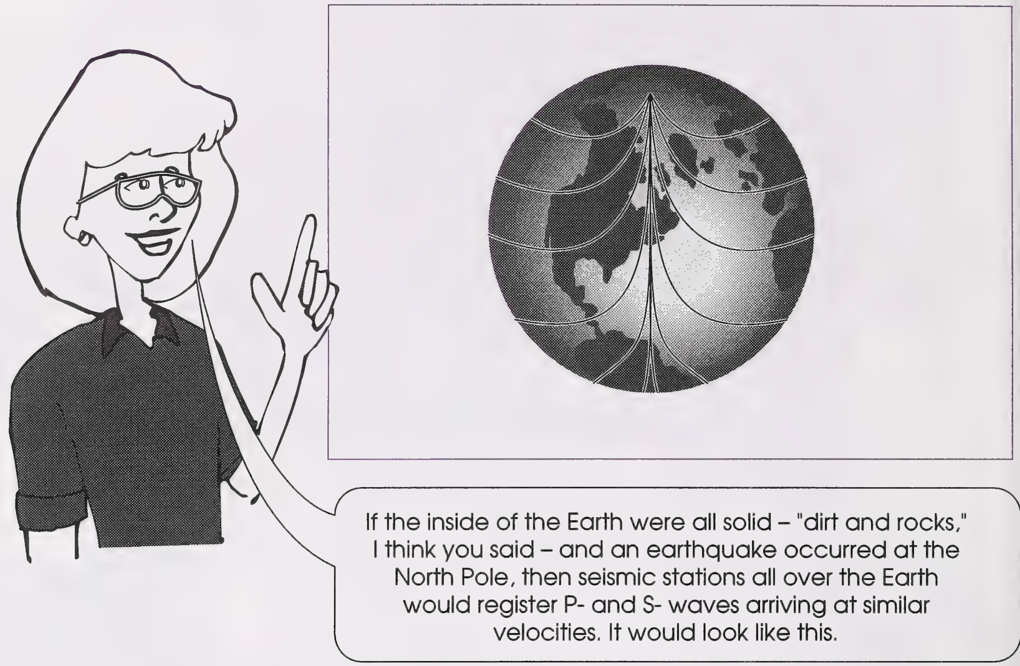
Check your answers by turning to the Appendix, Section 1: Activity 5.

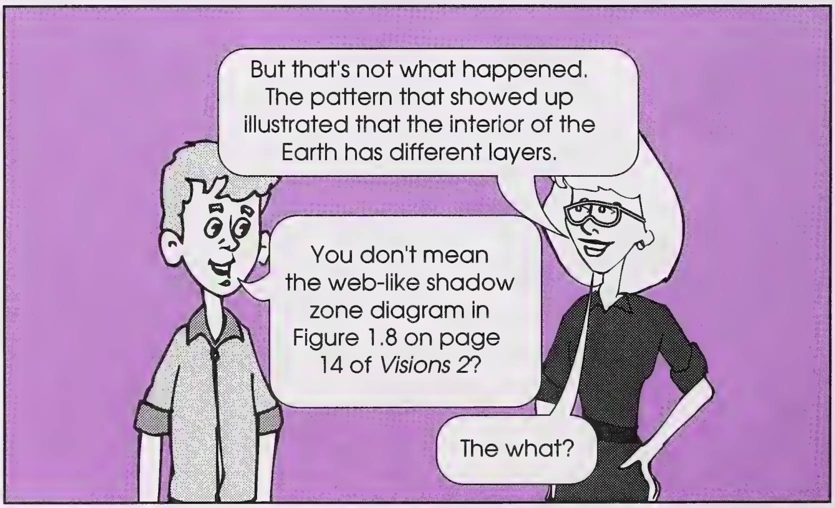


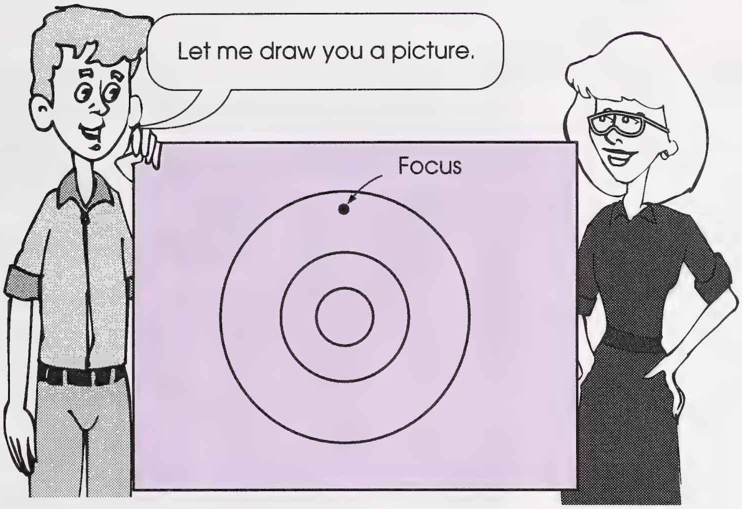
3. Copy and fill in the blanks in the following speech bubble.




So, you saw the light!
Yeah! Draw me a picture!
Get serious - do you want to know or not?
Well, actually two things are significant. First, light waves are refracted (or bent) when going from a substance of one density to that of a different density. That's why a stick looks bent when you put it in water.
I think I just found out why my pencil looked bent when I stuck it in Joe's glass of water at lunch.
You did what?!
Never mind. It's funny how science seems to creep up just about everywhere. So what's all this got to do with the inside of the Earth?
I was just getting to that.


If the inside of the Earth were all solid – "dirt and rocks," I think you said – and an earthquake occurred at the North Pole, then seismic stations all over the Earth would register P- and S- waves arriving at similar velocities. It would look like this.


But that's not what happened. The pattern that showed up illustrated that the interior of the Earth has different layers.
You don't mean the web-like shadow zone diagram in Figure 1.8 on page 14 of *Visions 2*?
The what?



4. Complete the diagram in the previous cartoon to show how P- and S-waves pass through the Earth's interior.

Check your answers by turning to the Appendix, Section 1: Activity 5.

If you can obtain the video entitled *Earth's Interior* from the *Earth Revealed* series, ACCESS Network, then watch the video and answer questions 5 and 6. You may be able to obtain this video from your local library or through a local school. This video will review Activity 5 as well as some of the ideas in Activities 2 to 4.

5. List three indirect methods used by scientists to determine the composition of the Earth's interior.

6. Describe how seismic data was generated and then used to investigate the structure of the Earth.

Check your answers by turning to the Appendix, Section 1: Activity 5.

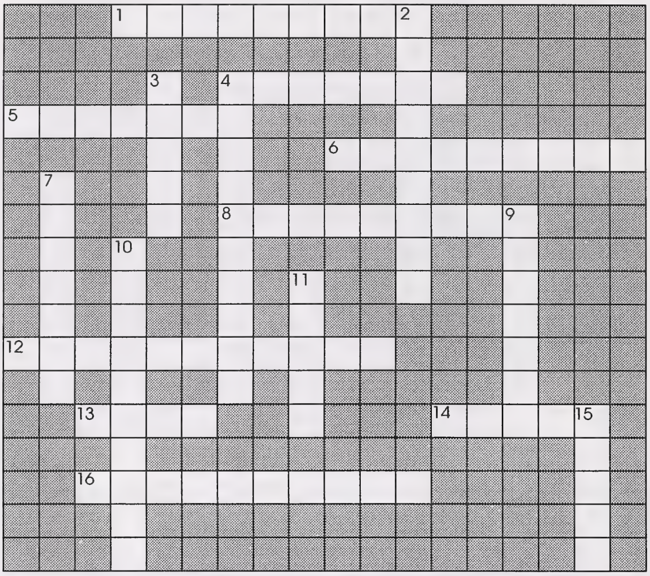
VISIONS

7. Study Plate 1.2 on page P-1 of *Visions 2* (the coloured pages). Identify and describe the following layers of the Earth. Use a diagram to help with your description.

   • lithosphere • asthenosphere • mesosphere

8. Reread page 14 of your textbook and describe the technological device called Superpress. How is it used? What do seismologists hope to learn by using it?

9. Complete the following crossword puzzle.



Across

1. ____________________ is the distance from the rest position of a wave to its maximum displacement.

4. The kinetic energy of earthquakes travels as ____________________ waves.

5. L-waves are seismic waves that travel along the ____________________ of the Earth.

6. The number of wave crests to pass a fixed point in a particular time is called the ____________________ of the wave.

8. The amount of energy released at the focus of an earthquake is called its ____________________.

12. A ____________________ is a device used to produce a record of seismic activity.

13. S-waves and P-waves are called ____________________ waves because they pass through the Earth's interior.

14. The source of an earthquake is called its ____________________.

16. In a ____________________ wave, particles of matter vibrate perpendicular to the direction of wave propagation.

Down

2. The point on the Earth's surface directly above the focus of an earthquake is the ____________________.

3. Seismic energy travels in the form of ____________________.

4. ____________________ is the study of earthquakes and the Earth's crustal movements.

7. The magnitude of an earthquake is measured on the ____________________ scale.

9. The modern theory of earthquakes is the ____________________ rebound theory.

10. A ____________________ is the record of ground motion produced by a seismograph.

11. A ____________________ is the fastest seismic wave. (It is also called a primary wave.)

15. An ____________________ is an example of a transverse wave.

Check your answers by turning to the Appendix, Section 1: Activity 5.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

PATHWAYS

If you have access to the video entitled *Earthquakes* from the *Earth Revealed* series, Magic Lantern Communications Ltd., do Parts A and B. If you do not have access to this video, do Parts B and C.

Part A

Watch the video and use the information presented to answer questions 1 to 3. You may be able to obtain this video through your local library or school.

1. Use the following terms to describe what happens in the Earth's crust before, during, and after an earthquake.

   - stress
   - elastic limit
   - energy transfer
   - fault
   - vibrate
   - seismic waves

2. Complete the following chart to compare P- and S-waves.

Wave Type	Description of Wave Type
P-wave	
S-wave	

3. The video describes many of the data recording devices used to monitor ground motion around Parkfield.

   a. Why was this location chosen?

   b. What are the goals of this research?

Check your answers by turning to the Appendix, Section 1: Extra Help.

End of Part A

Part B

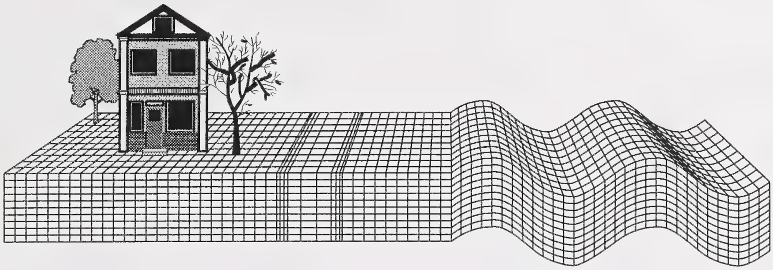
Seismic stations collect data that allows scientists to determine the location and strength of an earthquake.

4. Use each of the following three terms in a sentence to show how they are related.

   a. seismometer, seismograph, seismogram

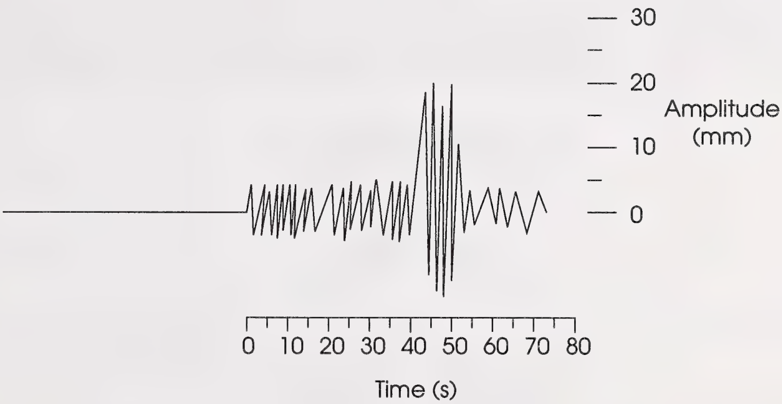
   b. earthquake, magnitude, Richter

5. Seismic waves, released when an earthquake occurs, cause motion in two directions: back and forth (longitudinal) and up and down (transverse). Study the following diagram; then describe the motion of the ground under the house when the P-wave reaches it, and then when the S-wave reaches it.



Wave	Ground Motion
P-wave	
S-wave	

6. Seismic data can be used to determine the magnitude of an earthquake. Use the following seismogram and the scales of distance, magnitude, and amplitude on page 13 of *Visions 2* to determine the magnitude of the earthquake. (Follow Steps 1 to 4 as outlined)



Step 1: Indicate the arrival of P- and S-waves on the seismogram.

Step 2: Calculate the difference in arrival time between P- and S-waves.

Step 3: Locate S – P on the scale to determine distance. (Note: Do not mark your textbook.)

Read the amplitude (mm) and locate the value on the appropriate scale. (Note: Do not mark your textbook.)

Connect the point on the distance scale with that on the amplitude scale with a ruler.

Step 4: Read the magnitude of the earthquake where the ruler cuts through the magnitude scale.

VISIONS

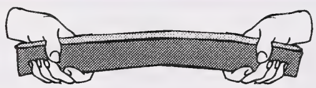
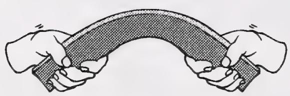
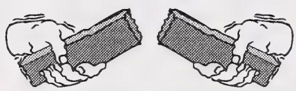
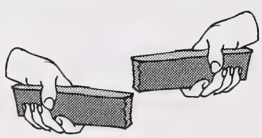
7. Earthquake prediction is important to humans. Answer question 2 on page 34 of your textbook.

Check your answers by turning to the Appendix, Section 1: Extra Help.

End of Part B

Part C

Earthquakes are the result of an energy transfer. Forces build up potential energy which is released when a fracture occurs. Make a chart like the one that follows:

Elastic Rebound of Wood	Earthquake Correlation
	
	
	
	

8. In the left-hand column of the chart, you will see a series of pictures showing what happens to a piece of wood that is bent until it breaks. In the right-hand column, describe how each picture correlates to what happens in the Earth's crust before, during, and after an earthquake. Try to use terms such as stress, elastic limit, rebound, and vibration in your descriptions.

9. Three different types of seismic waves occur during an earthquake. Copy and complete the following chart by giving the characteristic associated with each type of wave. These characteristics would include speed, direction of particle movement, and where the waves travel – on the surface or through the interior of the Earth.

Wave	Characteristics
P-waves	
S-waves	
L-waves	

VISIONS

10. Structural engineers must consider many factors when building in an earthquake zone. Answer checkpoint question 3 on page 34 of your textbook.

Check your answers by turning to the Appendix, Section 1: Extra Help.

End of Part C

Enrichment

Do any two of the following.

Science Skills
- ☑ A. Initiating
- ☑ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

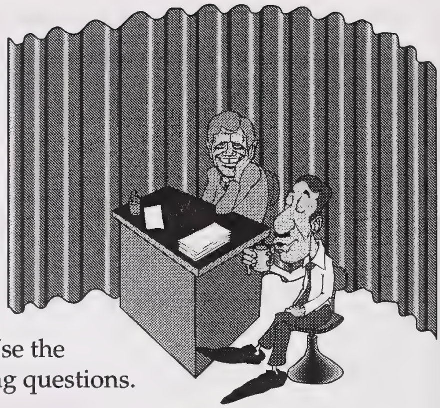
1. If you have access to a ripple tank, use it to design and carry out experiments to further investigate the nature of waves. (See the Appendix section of this module for suggested activities.)

Science Skills
- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

2. Design and construct your own seismograph. Use it to measure vibrations from machinery or your portable stereo. Design and write up an investigation to study the relationships between the intensity of vibrations and the seismic record produced. Include a hypothesis in your investigation and use the seismograph to verify your hypothesis.

Science Skills
- ☑ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

3. Visualize yourself as the host of a talk show. You have invited a survivor of the 1989 San Francisco earthquake to speak on the show. Make a list of at least twelve good questions to ask your guest. Your questions should present useful and interesting information.



4. Watch the video entitled *Living With Earth: Part 1* of the *Earth Revealed* series, ACCESS Network. You may be able to obtain this video through your local library or school. Use the information presented to answer the following questions.

   a. Just after the earthquake, rescue workers were advising people on what to do. What was their advice?

   b. Write a paragraph to explain why the Marina district of San Francisco suffered so much more damage than other parts of the city.

   c. Explain how the geologists' work was threatened by the efficiency of the repair crews.

   d. List five things people can do to limit the impact of earthquakes.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

In this section you learned that when forces within the Earth cause rock layers to break, tremendous amounts of energy is released. This energy travels in waves – moving the ground and causing earthquakes. You investigated and discovered the importance of seismographs and their use in monitoring seismic waves. You learned that scientists can use seismic data to study earthquakes as well as propose theories about the nature of the Earth's interior.

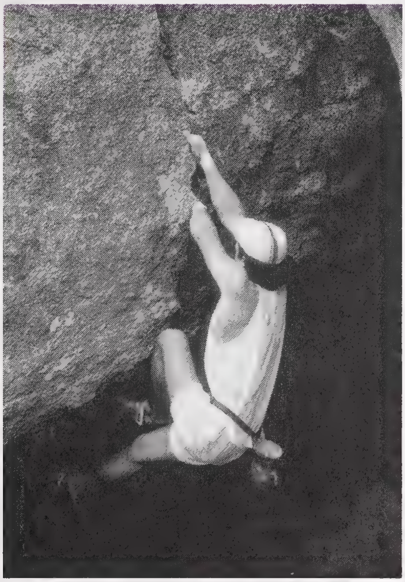
In the next section you will learn more about the interior of the Earth and the forces that can compress, stretch, bend, and break rock layers.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

Section

2 The Theory of Plate Tectonics



Chances are if you ask the climbers why they are climbing the mountain, they will tell you because it's there. Why is it there? Have you ever wondered? Will the mountains always be there? One thing is for certain, a great deal of energy was required to form these great piles of rock! They certainly seem solid, immovable, and permanent.

In Section 1 you learned that the Earth is not solid throughout, but that its rocky surface is really just a shell covering semi-solid layers of rock. Scientists have long looked to this fluid region of the Earth's interior as a source for the tremendous forces working to shape its surface.

In this section, you will further examine this view of Earth to discover that its surface is actually a cracked shell and that the pieces of this shell are constantly moving. So, no matter where you are on the Earth's surface, you are being taken for a ride! This is the theory of plate tectonics.

Section 2 will explain the tectonic theory and help you to examine some of the evidence that first led scientists to propose it. You will discover how the theory is used to explain geological phenomena from earthquakes and volcanoes to the formation of mountains. You will then be asked to apply what you have learned to predict geological phenomena off the coast of British Columbia.

Activity 1: Looking at the Evidence

Did you know ancient people thought the Earth was flat and even told stories about how it was carried around on the back of a turtle? People have always been curious, searching for explanations. So when you ask yourself why there are mountains, you're not the first.

Ancient Mountain Builders

According to ancient Greek and Roman myths, the mountains were built by giants attempting to build a stairway to the gods. Zeus, the Greek king of gods, used thunderbolts to strike down this stairway into rugged mountain chains. He then imprisoned the giants beneath the Earth's surface. They in turn broke the Earth's crust in an effort to escape and hurled molten rock at the heavens.

The myth may seem like a simple story; but when you consider it carefully, you see that it is based on observations of the natural world. For example, liquid rock does come from under the Earth's surface through mountain tops – often with explosive force.

1. Cite another example from this myth that indicates these ancient people were observers of nature.

Check your answers by turning to the Appendix, Section 2: Activity 1.

People really haven't changed all that much. They still observe nature and draw on their understanding of it to develop theories that can explain what they observe. Science has always been, and still is, a very natural human activity.

Continental Drift

The theory of plate tectonics began with keen observations and natural curiosity. During the age of exploration, when the world was being mapped, it was noticed that the coastlines of Africa and South America looked like they could fit together.

Around 1910 a German meteorologist, Alfred Wegener, noticed this fit and went on to suggest a reason.

Read pages 17 and 18 of your textbook to learn more about continental drift; then answer question 2.

2. Explain Alfred Wegener's theory of continental drift.

Check your answers by turning to the Appendix, Section 2: Activity 1.

When Wegener tried to find support for his supercontinent, he went about it in much the same way as you put a new puzzle together. Wegener viewed the world as a giant jigsaw puzzle and tried to fit the pieces together to see what he could "read."

Do the following investigation to get some idea of what Wegener was up against, and what he was able to discover.

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

Investigation: Rejoining the Continents

Follow the directions of this investigation carefully. Pay special attention to the required components and applied science skills.

Problem

Could the continents have been joined together as a single land mass in the past?

3. State a hypothesis in answer to the problem.

Materials

- world map (provided in Appendix)
- scissors
- tape or glue
- sheet of paper

Procedure

Step 1: Use the map provided in the Appendix of this module. With your scissors, cut along the dotted lines around the continents. (These are meant to represent the edges of the continental shelves.)

VISIONS

Step 2: Move the land masses around on your sheet of paper until they are arranged into a single land mass in which all evidence seems to fit together. Check page 17 of your textbook for the arrangement.

Step 3: Use tape or glue to secure this arrangement.

Observations

On the basis of the arrangement you developed, answer the following questions.

4. Do any of the edges along one continental shelf appear to match closely with another? If so, which?

5. Do any glacial patterns appear to indicate movement of glaciers from one land mass to another? If so, where?

6. Where do the zones of ancient mountain chains suggest a close relationship between two land masses?

7. Are there some areas along the edges of the land masses which overlap? If so, where are they?

Analysis and Interpretation

On the basis of your observations, answer the following questions.

8. Why were you asked to use the edge of the continental shelf to match the land masses rather than the shorelines?

9. How could you explain any areas which appeared to overlap?

10. Copy the following chart and explain how each of the following pieces of evidence supports the theory that the continents were once joined.

Evidence	Explanation
shapes of continents	
glaciation	
ancient mountains	
age of rock making up continental foundations	

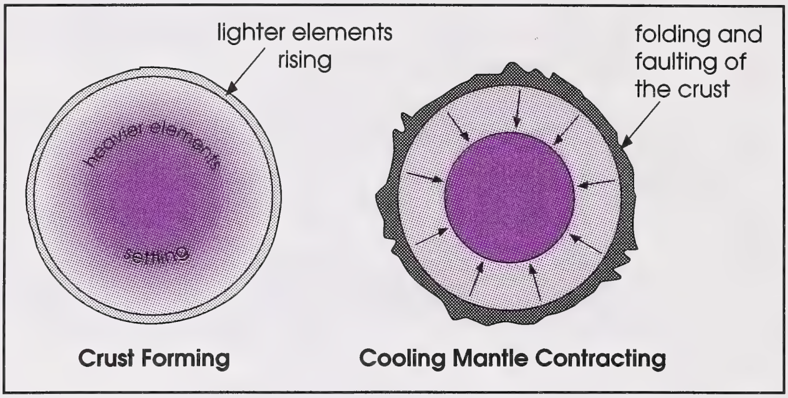
11. State a conclusion for your investigation. Does your conclusion support your hypothesis?

Check your answers by turning to the Appendix, Section 2: Activity 1.

In a jigsaw puzzle, you are able to use the edges of the pieces to fit all the pieces together. Wegener used the shapes of the continents to reconstruct his supercontinent. In the previous investigation you were able to recognize the picture as the supercontinent which proves that you have put the pieces together correctly. Wegener too felt he could read a message in his reconstruction. This prompted him to propose his theory of continental drift.

To learn more about Wegener, his theory and how it was received by the scientific community, view the video *The Birth of a Theory*, from the *Earth Revealed* series. Review questions 12 to 16 before you watch the video. Use the information presented in the video as well as the information on pages 17 and 18 of *Visions 2* to help you answer questions 12 to 16.

12. As shown in the following diagram, scientists during Wagner's time believed that the Earth formed in a molten state and is still in the process of cooling, solidifying, and contracting.



Explain how scientists use this theory to explain the following:

a. mountain formation

b. the similarity of life-forms on continents separated by oceans

13. Why did Wegener doubt the shrinking Earth theory?

14. Why was Wegener's theory of continental drift not readily accepted?

15. The discovery of what geological feature prompted the theory of ocean floor spreading?

16. Name the technology that made the discovery of this feature possible. What societal issue led to the development and subsequent use of this technology? What was the purpose of the technology at this time?

VISIONS

Check your answers by turning to the Appendix, Section 2: Activity 1.

Birth of Plate Tectonics

Science Skills

- ❒ A. Initiating
- ❒ B. Collecting
- ☑ C. Organizing
- ❒ D. Analysing
- ❒ E. Synthesizing
- ❒ F. Evaluating

Read pages 19 to 21 of your textbook. Use this information to help you answer questions 17 to 23.

17. Describe a prediction put forth by paleomagnetic scientists that was based on the theory of ocean floor spreading.

18. Explain how this prediction was tested.

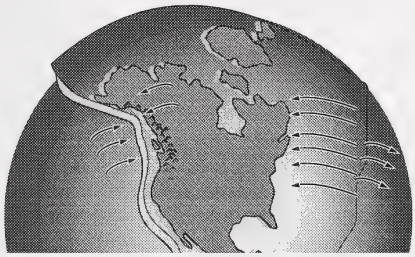
19. Use a diagram to help summarize the results of these tests.

20. Explain how the results of these tests supported Wegener's theory of a supercontinent.

21. Explain how the work of the Canadian geophysicist Tuzo Wilson supported the idea that the continents were once much closer together.

22. Describe the theory of plate tectonics.

23. Use the following diagrams to help you explain the difference between Wegener's theory of continental drift and the theory of plate tectonics.



Check your answers by turning to the Appendix, Section 2: Activity 1.

In this Activity, you have examined evidence to support the theory that the crust of the Earth is divided into slabs that are moving. You will recall from previous science studies that a force is required to initiate motion. The driving force of crustal plate motion is the subject of the next activity.

Activity 2: Convection – The Driving Force for Plate Tectonics

In Activity 1 you were presented with an accumulation of evidence that prompted scientists to propose the theory of plate tectonics. Review this evidence, then answer question 1.

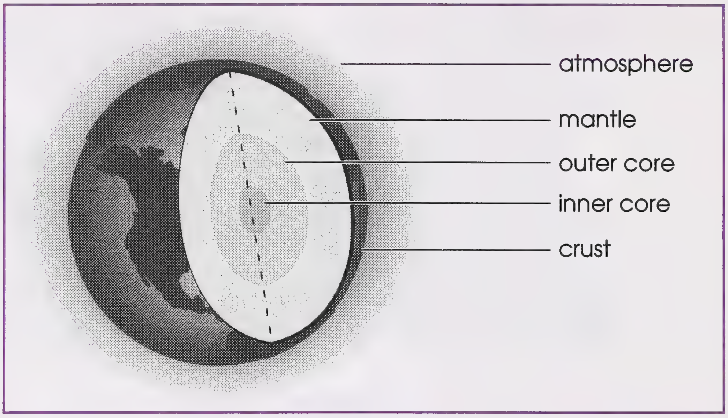
1. Of all the evidence presented to support crustal movement, which seemed the most convincing to you. Explain why.

Activity 1 also suggested that the source of the energy supplying the forces necessary to move crustal plates lies underground.

The Earth's Surface Moves

The Earth's crustal plates are moving; therefore, a force (or forces) must be acting on them. You know that a force is a push or a pull; so something is pushing, or pulling, on the plates.

The crust of the Earth is in contact with the atmosphere above it and the Earth below it. Look at the following diagram.



Therefore, both the atmosphere and mantle are interacting with the Earth's crust. The question is, what is providing the force(s) required to move the crustal plates? Study the following graphic, and answer questions 2 and 3.

2. Consider both of the hypotheses presented in the graphic. Develop arguments to illustrate that neither hypothesis is a valid explanation of the forces that are responsible for tectonic movement.

3. State your hypothesis to explain tectonic movements. What do you think is the driving force of plate tectonics?

Check your answers by turning to the Appendix, Section 2: Activity 2.

VISIONS

Compare your hypothesis to the currently accepted model by reading pages 20 and 21 of your textbook.

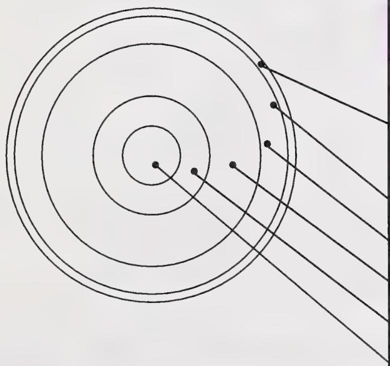
A Model of the Earth's Interior

In Section 1 of this module you discovered that scientists developed a model of the Earth's interior based primarily on indirect evidence such as seismic data. By measuring temperatures within the crust, geophysicists also used direct data to confirm that the Earth's interior is hot. Measurements within the top 10 km of the Earth's surface show that the temperature rises steadily with depth, at an average rate of 25° C for every kilometre.

VISIONS

Refer back to Plate 1.2 on page P-1 of your textbook. Review the model of the Earth's interior, and answer question 4.

4. Construct and complete a chart similar to the one in the following diagram.



Depth (km)	Layer	Description
0 – 100	lithosphere	• cool • solid • brittle

Check your answers by turning to the Appendix, Section 2: Activity 2.

Scientists have developed theories to explain why layers exist in the Earth's interior as well as to explain the tremendous geothermal energy stored underground. To find out more about these theories, you may choose to complete the Enrichment at the end of this section.

VISIONS

Read the Did You Know feature on page 20 of your textbook; then answer questions 5 and 6.

5. What did Arthur Holmes believe to be the source of heat in the Earth's interior?

6. Explain why convection currents are thought to exist in the mantle.

Check your answers by turning to the Appendix, Section 2: Activity 2.

Investigation: Observing Convection Currents in Action

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

If you have a glass cooking pot, you may perform this investigation. Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Purpose

To observe convection currents in a fluid created by a heat source

Materials

- glass cooking pot
- 1 cup rolled oats
- 2 cups water
- heat source

Caution

Procedure

Step 1: Add 2 cups of water to a glass cooking pot and bring the water to a boil. Work carefully when using any heat source.

Step 2: Measure 1 cup of rolled oats, and add a little to the boiling water.

Step 3: Observe the motion of the porridge mixture from the side.

Step 4: Draw a diagram of how the porridge mixture moves.

Step 5: Add the remaining rolled oats. Continue to observe the motion of the porridge mixture from both the side and the top. Note any observations about the motion of the porridge mixture.

Step 6: Observe the porridge from the top when it gets thick and starts to bubble.

Observations

7. Write down what you observed and draw diagrams showing the motion from the sides and the top of the pot.

Analysis and Interpretation

8. Do you think the motions you observed in the preparation of porridge are typical of any fluid which is being heated?

9. If the composition of the Earth's magma is fluid-like, do you think similar motions could be occurring in the magma?

Check your answers by turning to the Appendix, Section 2: Activity 2.

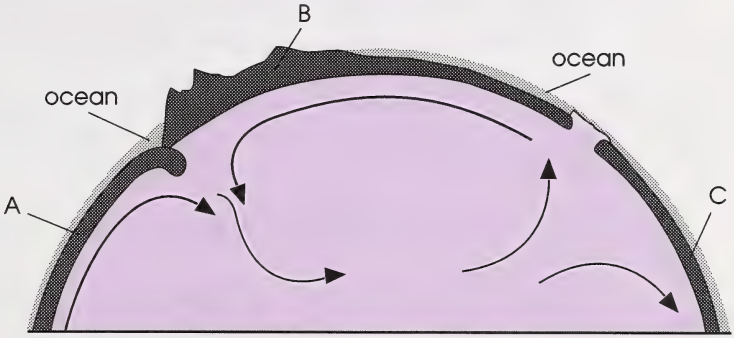
Plate Movement

VISIONS

Study Figure 1.12 on page 21 as well as the diagrams and text in Table 1.4 on pages 22 and 23 of your textbook to help you answer questions 10 to 13. You may also wish to refer back to information given on page 20.

10. Explain how convection currents in the mantle can cause crustal plate movement.

Use the following diagram for questions 11 to 13.



11. Identify and describe the two different types of crustal plate material (labelled A and B). (You may find it helpful to refer to Plate 1.2 on page P-1 in your textbook.)

12. Describe how the following plates are moving in relation to each other.

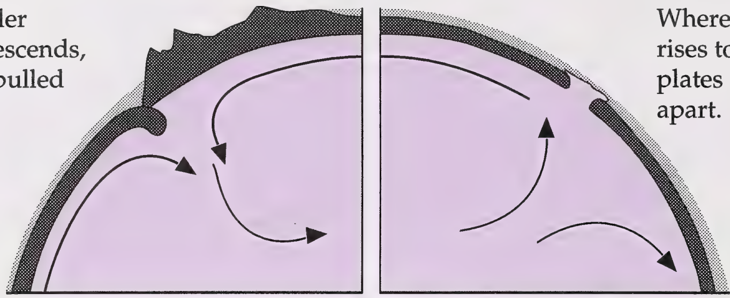
    a. A and B   b. B and C

13. Explain why plate A slides under plate B.

Check your answers by turning to the Appendix, Section 2: Activity 2.

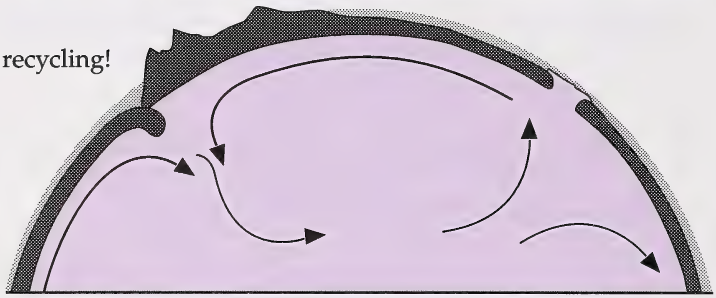
Activity 2 has presented convection currents in the semi-solid mantle of the Earth's interior as the driving force for plate tectonics.

Where cooler material descends, plates are pulled down.



Where hot material rises to the surface, plates are pushed apart.

Talk about recycling!



The tremendous forces that can move crustal plates about also deform (reshape) the lithosphere, creating a wide array of geological phenomena. If you would like to know more about plate movement, do question 3 in the Enrichment.

What happens to the lithosphere at plate boundaries is the subject of the next activity.

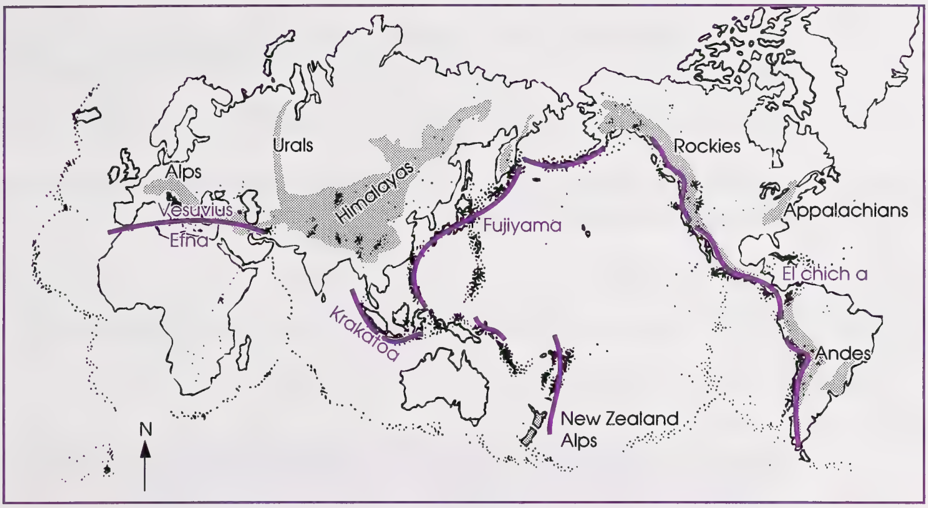
Activity 3: Explaining and Predicting Geological Phenomena

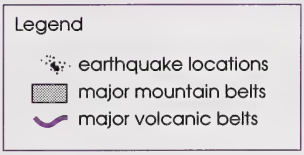
Activities 1 and 2 of this section have introduced you to the theory of plate tectonics. A good theory should help explain observations and help predict future events. Activity 3 will ask you to use the theory of plate tectonics to do just that. You will be asked to use this theory to explain geological phenomena such as earthquakes, volcanoes, and mountain ranges.

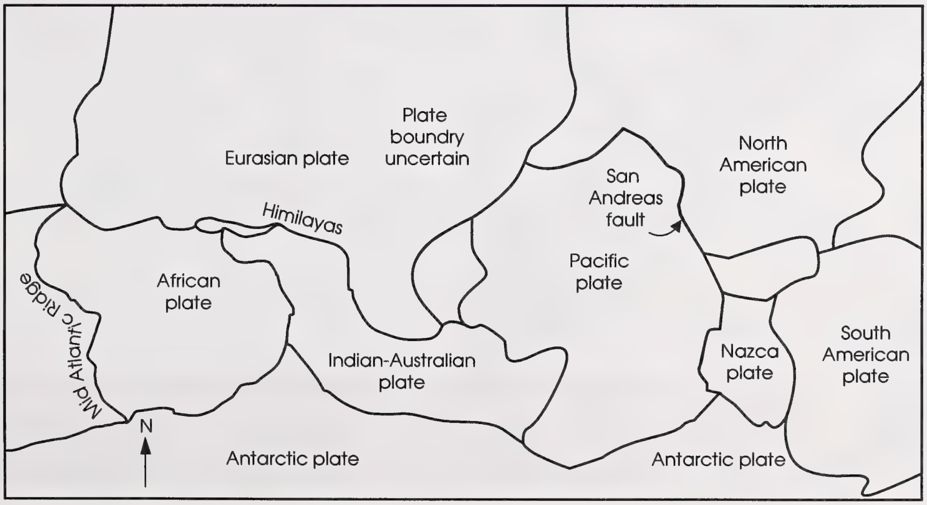
You will also be asked to use the theory of plate tectonics to predict changes to the geologically active areas on the west coast of Canada.

Plate Tectonics Is Used to Predict Geological Phenomena

Study the following maps as you read the description which follows these maps.







The first of the previous maps shows the earthquake locations (represented by the black dots), the major mountainous areas (represented by the light grey regions), and the major areas of volcanic activity (represented by the coloured strips).

The second map shows the tectonic plates that scientists believe make up the crust of the Earth. Study the plate boundaries and how these boundaries would fit with the geological phenomena on the first map. Try to visually fit the second map onto the first.

The two maps have been reproduced at the back of the appendix. Use this copy to overlay the tectonic plates over the map of the geological phenomena. You will find it helpful to hold the maps up to the light when you do the overlay. Answer questions 1 to 3 based on your observations.

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

1. Make observations concerning the relationship between the following geological phenomena and plate boundaries.

   a. earthquakes　　b. volcanoes　　c. mountain chains

2. Write a problem statement (question) for each of the previous observations.

3. State a hypothesis for each problem generated in question 2.

Check your answers by turning to the Appendix, Section 2: Activity 3.

VISIONS

Clearly, where plates meet, things happen! To learn how the theory of plate tectonics can be used to explain these and other geological phenomena, study pages 21 to 24 of your textbook. Use this information to answer the following questions.

4. Use the theory of plate tectonics to explain how and why each of the following geological phenomena occurs along the boundaries between plates.

   a. earthquakes　　c. mountains

   b. volcanoes　　d. island arcs

5. Indicate on the following scale how successful you think the theory of plate tectonics is at explaining changes to the Earth's surface. Justify your rating.

1	2	3	4	5
not very successful				extremely successful

Check your answers by turning to the Appendix, Section 2: Activity 3.

seismic gap – areas along plate margins where no earthquake activity is occurring

Apply your knowledge of the theory of plate tectonics to predict geological activity off Canada's west coast by completing the following investigation. In this investigation you will learn about the various faults off the coast as well as about areas known as seismic gaps.

Investigation: Predicting and Locating Geological Activity

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

VISIONS

Follow the directions of this investigation carefully. Pay special attention to the required components and applied science skills.

Background Information

Read over the Planning section of Activity 1.3 on page 24 of your textbook, and use Plate 1.4 on page P-2 (coloured pages) of your textbook to help you complete questions 6 to 9.

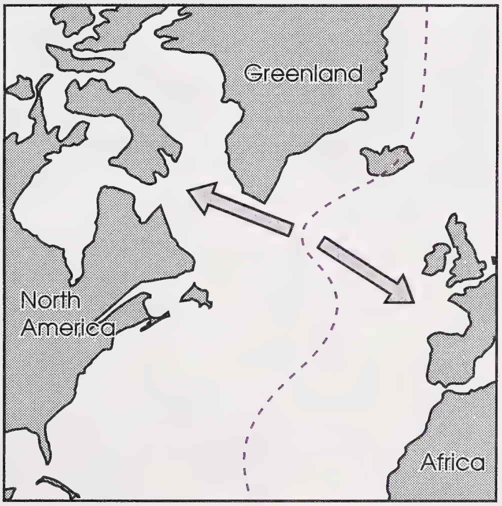
6. Sketch a diagram of the west coast of Canada showing the fault line just off the coast of British Columbia. Label the plates and draw in arrows to show the motion of the plates relative to each other. Label the fault zones.

7. Plate boundaries vary. Name and describe three types of plate boundaries found off the west coast of Canada.

8. Name the major plates responsible for these boundaries along the west coast of Canada and describe their motion in relation to each other.

9. Name three areas in western Canada subject to more frequent earthquake activity than other parts of Canada. Explain why these areas are more active.

10. The diagram shows the mid-Atlantic ridge which is the closest plate boundary to eastern Canada. In the diagram, eastern Canada is well away from a plate boundary. However, it has significant earthquake activity. What might explain this? Formulate a hypothesis.



Read the remainder of Activity 1.3 on pages 24 to 26 of your textbook, and complete the investigation.

Purpose

11. State the purpose of this investigation.

Materials

- Table 1.4 from page 22 and 23 of *Visions 2*
- Plate 1.4 from page P-2 of *Visions 2*
- atlas with a physical map of the west coast of Canada and of the world

Procedure

Study both Plate 1.4 and the physical maps of the west coast and of the world carefully; then use them to complete the Analysis and Interpretation questions that follow.

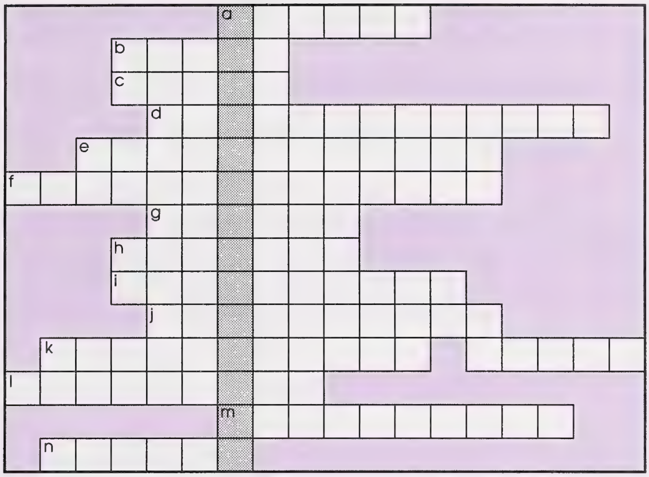
Analysis and Interpretation

12. Answer questions 1, 2, 3, 5, and 7 on pages 25 and 26 of your textbook. (Note: Geological features refer to such things as mountain chains. A topographical map refers to a map of the physical features.) For question 5 use a scale of 1 cm = 250 km for Plate 1.4 in *Visions 2*.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Activity 3 has illustrated the success of the theory of plate tectonics at providing explanations for a variety of changes to the Earth's surface. Read the summary on pages 34 and 35 of your textbook; then review the concepts covered by completing the following word puzzle.

13. Make and complete the following puzzle. Discover the mystery term spelled out by the highlighted letters.



a. a term used to refer to segments of the lithosphere

b. a fracture in the Earth's crust

c. apparatus used to map the ocean floor

d. thick, hot layer of the Earth that lies immediately beneath the crust

e. a sensitive compass used to detect the magnetism in rocks

f. a scientist who studies fossils and ancient life

g. a depression in the ocean floor caused by plate subduction

h. occurs where magma from the Earth's interior is expelled through ruptures in the Earth's surface

i. a sudden vibration or movement of the Earth's crust

j. the type of energy contained under the Earth's crust

k. a theory first proposed by Alfred Wegener to explain the fit of continental coastlines

l. a scientist who studies the structure of the Earth

m. the source of the force used to explain the movement of Earth's plates

n. geological features that result when magma rises through rifts in the Earth's crust

Check your answers by turning to the Appendix, Section 2: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

1. Complete the following statements by inserting the appropriate words from the list provided.

- ocean floor spreading
- continental drift
- plates
- magma
- geothermal
- spreading
- plate tectonics
- tectonic plates
- asthenosphere
- convection

The following is a collection of data Alfred Wegener used to help support his theory of ____________________.

- fossils of a *Mesosaurus* were found in Brazil and South Africa
- rocks of mountain ranges in eastern North America matched rock found in Scotland and Norway
- mountain ranges in South Africa matched ones found in Argentina
- scratches in ancient rock showed that South Africa and South America were once covered by the same glacier

Oceanic ridges discovered by sonar gave rise to the theory of ____________________.
The striped pattern of normal and reverse magnetism imprinted in the rocks on both sides of oceanic ridges prompted scientists to conclude that the oceanic crust is ____________________ at oceanic ridges. According to the theory of ____________________, the Earth's lithosphere is broken into ____________________.
Scientists theorize that these plates slide over the ____________________ driven by ____________________ currents. ____________________ energy causes a difference in density of the materials that make up Earth. Rising ____________________ and subducting ____________________ result in diverse geological phenomena at plate boundaries.

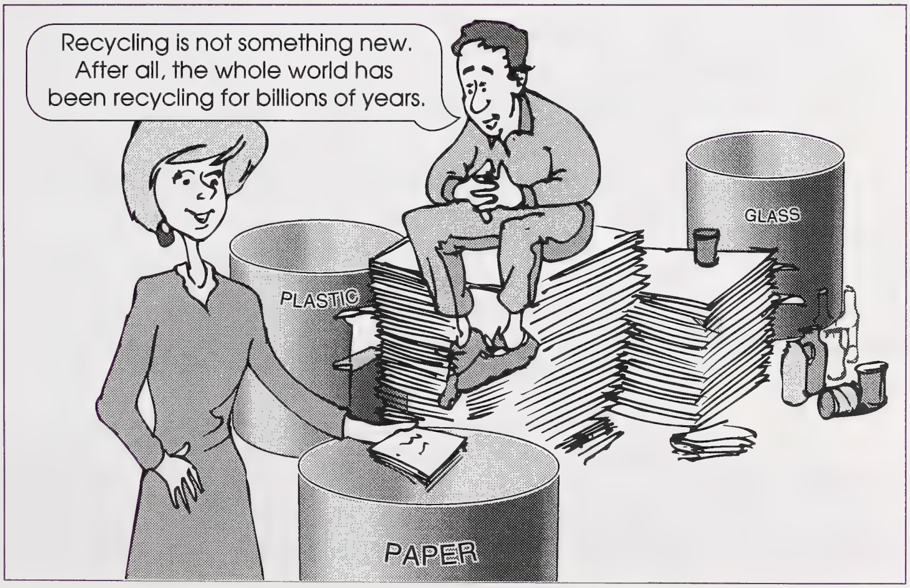
VISIONS

2. Answer question 1 on page 28 of your textbook.

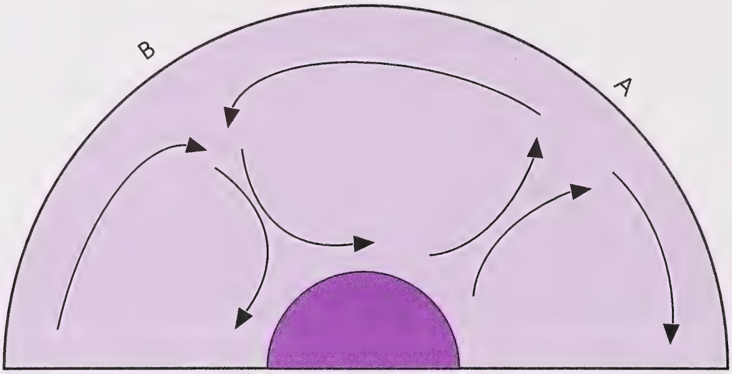
3. Do either a or b.

   a. Answer question 2 on page 28 of your textbook.

   b. Explain what the character in the cartoon means in saying, "the whole world has been recycling for billions of years."



4. Copy and complete the following diagram by showing geological features likely to occur at A and B. Explain why.



5. Answer question 3 on page 28 of your textbook.

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

Do one or two of the following.

1. Write a paragraph to support or dispute the following statement.

   The initial rejection of Wegener's theory by the scientific community reflected responsible science rather than closed-minded, traditionalist thinking.

   Support your opinion by fully explaining why you think as you do. Whenever possible, include examples.

2. Watch the video entitled *The Restless Planet* from the *Earth Revealed* series; then answer the following questions.

   a. How do scientists believe the Earth was formed?

   b. How do scientists explain the extremely high temperatures in the Earth's interior?

   c. How do scientists explain the layering of the Earth's interior?

3. For a greater understanding of plate movement, watch the video entitled *Plate Dynamics* from the *Earth Revealed* series Magic Lantern Communications Ltd.; then answer the following questions. You may be able to obtain the video through your local library or school. It is best if you review the questions before you watch the video.

   a. What are three types of plate merging occurring at plate boundaries? Give an example of where each type of merging is occurring on Earth.

   b. Why is the interior of the Earth convecting?

   c. Briefly explain the two-tiered process of convection in the Earth's mantle.

   d. What is the evidence for the two-tiered process of convection?

   e. What evidence have satellites provided to show that the Earth is convecting?

   f. Name and describe the special type of convection that occurs under the middle of the plates? What are two examples of areas where this special type of convection occurs?

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

In Section 2 you were presented with a theory that looks to the Earth's interior for an explanation of the forces that can form mountains, cause earthquakes and volcanoes, and a variety of other geological phenomena. Through Activity 1, you discovered the evidence that led scientists to the development of the theory of plate tectonics. In Activity 2 you were asked to evaluate how well this theory is able to explain geological phenomena. Activity 3 gave you the opportunity to apply this theory to predict the geological activity off the coast of British Columbia.

In the next section, you will continue your examination of forces that change the Earth's surface by studying glaciers and their effect on the land. You will also discover what scientists have learned about ancient climates by studying glacial ice core samples.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 2.

Section

3 Glaciation

COURTESY OF RICK SABISTON

Alberta is a scenic wonder. You may recognize the area in the previous photograph as the Columbia Icefields. The overview to this module mentioned that almost all of Alberta was buried beneath a kilometre of ice 15 000 years ago. In fact, great ice sheets have come and gone several times in the last two million years. Many of Alberta's surface features owe their existence to these glacial cycles. This section will present technologies used by scientists in trying to solve the puzzle of how the Earth's surface came to be what it is today.

Once again you will see how careful observations of present surface features are used to paint a picture of the past and predict the future. Activity 1 will teach you how to read the land for evidence of glacial action and give you an understanding of present surface features. Activity 2 will present evidence of past glaciation and cyclic climate changes gained primarily through ice core sampling. You will also be asked to examine a theory currently used to explain these dramatic shifts in Earth's climate and the reoccurrence of the ice ages. Activity 3 will provide you with the opportunity of applying your knowledge to understanding the present state of the Earth's climate and to predicting the future. You will come to question the human impact on the natural cycle of Earth's climatic changes.

Activity 1: Visible Effects of Glaciation

It's easy to see how streams and rivers shape the land. You can see the land wearing away as the water plucks material from the banks and carries it along. It is far more difficult to see how glaciers can shape the land. You can't see them move – yet they carve their way across great expanses of land, transporting material for thousands of kilometres.

The till shown in the following photograph has been deposited by a glacier.

COURTESY OF RICK SABISTON

VISIONS

People weren't always aware of the impact glaciers have on land. Read page 86 of your textbook to discover who first brought the importance of glaciers to the attention of the scientific community. Answer questions 1 and 2 when you have completed the reading assignment.

1. Explain why it was difficult to persuade early scientists that huge glaciers had much to do with sculpting the Earth's surface.

2. What did Louis Agassiz's studies of valley glaciers in the Alps lead him to believe?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Surface features such as the big rocks shown in Photo 3.3 on page 87 of your textbook provide scientists with valuable clues. These clues help them understand the forces responsible for shaping the landscape of an area. Read page 87 and study Photo 3.3 and Figure 3.3 in the textbook. Use the information provided to answer questions 3 to 5.

3. Rocks can be found just about anywhere on the Earth's surface. Why do scientists believe the rocks in Photo 3.3 were deposited by glaciers?

4. How is a glacier like sandpaper?

Glaciers, like rivers, flow down hill. Rivers eventually reach an ocean. Glaciers continue their journey until they reach an altitude or latitude where the temperatures are such that melting occurs. From this point on the ice continues its journey as meltwater. The material carried along by the ice is deposited where the ice melts.

5. Figure 3.3 on page 87 of *Visions 2* uses the analogy of a conveyor belt to describe the motion of a glacier. Do you think this is an accurate analogy? Why or why not?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Glaciers are Formed from Snow

To review what glaciers are and how they form, study the following diagrams; then do question 6.

In areas where snowfall survives the summer melt season year after year, there will be a net accumulation of snow.

As snow is deposited it, begins to recrystalize. The points of each snowflake melt and evaporate to form small, round grains.

As new snow is added year after year, the underlying snow is compacted. The small grains of snow are squeezed into ice. When enough snow has accumulated to metamorphose snow into ice, the pile is thick enough to sag and flow downhill.

6. What is a *glacier*?

VISIONS

Read the Planning section of Activity 3.2 on page 88 of your textbook to discover how glaciers can be classified; then answer questions 7 and 8.

7. Name the two major types of glaciers and state where each type occurs.

8. Explain how it is possible for glaciers to exist in low latitude areas.

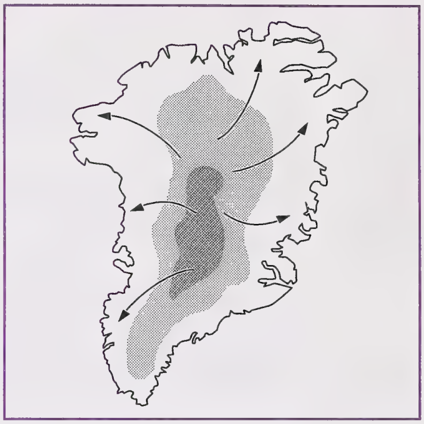
Check your answers by turning to the Appendix, Section 3: Activity 1.

Glaciers Move

ANGEL GLACIER COURTESY OF RICK SABISTON

Earlier in this module, you read that the accumulating mass of a glacier will cause it to flow from higher elevations to lower elevations. It's easy to understand how ice fields and valley glaciers which form high in the mountains can flow down mountain valleys to lower elevations as illustrated in the previous photograph. What about continental glaciers? How do they move? Study the following diagram; then answer questions 9 and 10.

The motion of continental glaciers can be compared to the pouring of pancake batter. When you pour pancake batter, it flows from the middle outward. Continental glaciers also spread outward. This is due to the mass in the middle.



9. What force makes continental glaciers move?

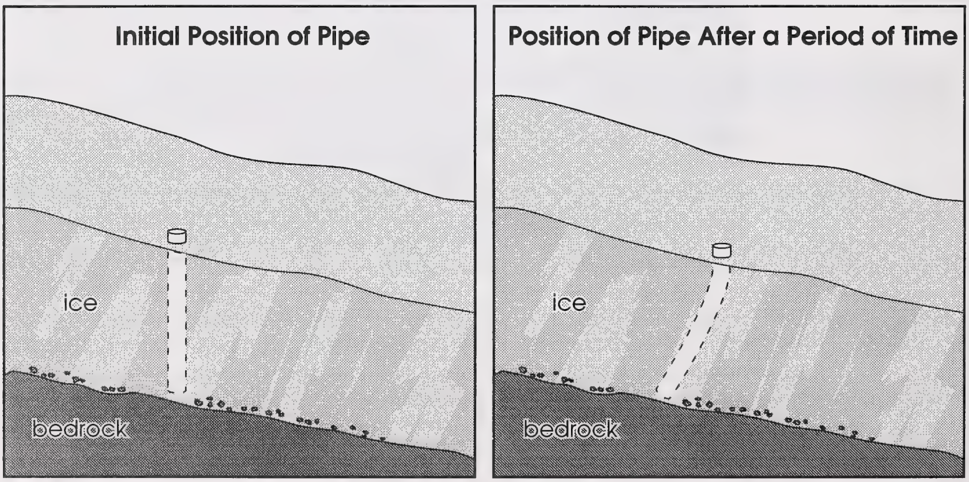
10. Describe how you could prove that a glacier moves.

Science Skills

- ☑ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Check your answers by turning to the Appendix, Section 3: Activity 1.

Scientists wishing to learn more about the movement of glaciers drilled holes through the ice and inserted flexible pipes. Changes in the shape and positions of the pipes were measured regularly. The following diagram illustrates the results of these studies. Interpret the information given in the diagram to answer questions 11 and 12.



Science Skills

- ❑ A. Initiating
- ☑ B. Collecting
- ❑ C. Organizing
- ❑ D. Analysing
- ☑ E. Synthesizing
- ❑ F. Evaluating

11. State an observation describing the movement of different parts of the glacier based on the previous illustration.

12. Make an interpretation based on your observation. Try to explain why the bottom of the glacier moves more slowly.

Check your answers by turning to the Appendix, Section 3: Activity 1.

Effects of Glacial Movement

As glaciers move they erode the Earth's surface. The following is a list of landscape features resulting from glacial erosion.

- cirque
- serrated linear crests
- U-shaped valleys
- smoothing
- striations

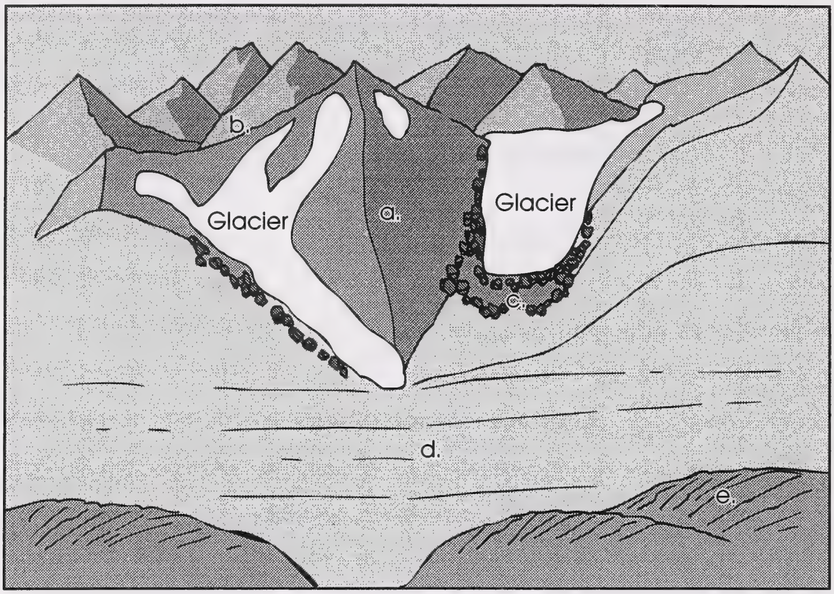
In the following photograph you can clearly see the U-shaped valley in the center and the serrated linear crests both on the left and the right of the glacier.

COURTESY OF DR. GERALD OSBORN

VISIONS

Read Steps 3, 4, 5, and 6 of the Procedure section in Activity 3.2 on pages 88 and 89 of your textbook for a description of these features and how they form. Use this information to label the following diagram.

13. Label the areas marked by the letters on the diagram with the following terms: cirque, serrated crest, U-shaped valley, striations, evidence of smoothing.

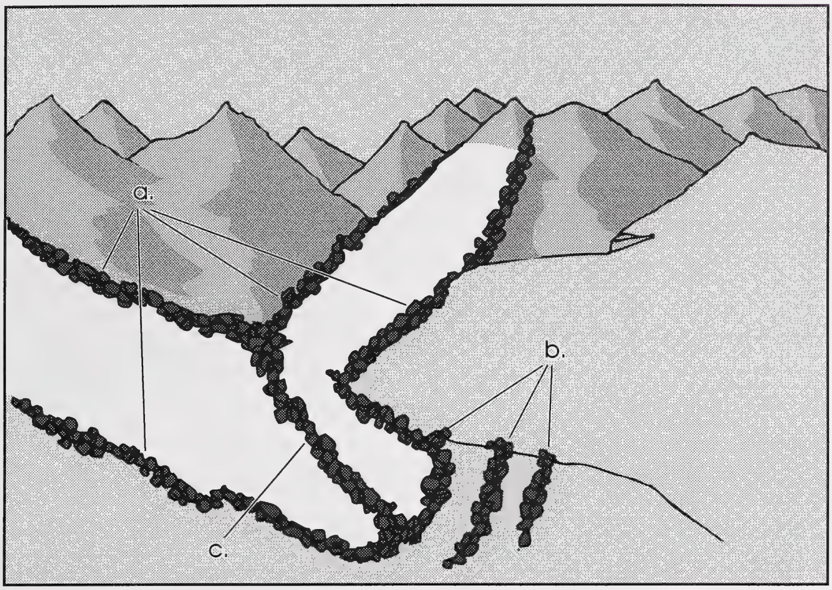


Check your answers by turning to the Appendix, Section 3: Activity 1.

VISIONS

Rock material of various size is carried along as the glacier moves and is deposited when parts of the glacier melt. The deposition of this material also changes the Earth's surface creating features such as the different moraines and the outwash plains described in parts 7, 8, 9, 10, and 11 of the Procedure section in Activity 3.2 of your textbook. Read this section, then answer questions 14 to 17.

14. The diagram that follows depicts the different types of moraine deposited by a glacier. Use the information from page 89 of your textbook to label the diagram, as indicated by the letters, using the terms end moraine, lateral moraine, and medial moraine.



15. Is the glacier in the previous diagram advancing or retreating? How do you know?

16. Describe the composition of the moraines.

17. Explain how glaciers can form outwash plains.

Check your answers by turning to the Appendix, Section 3: Activity 1.

Evidence of Glaciers in Alberta

Much of Alberta's landscape was sculpted by glaciers. Evidence of glaciation can be found not only in the mountains, but just about anywhere in Alberta. For example, the erratic shown in Figure 3.3 on page 87 of *Visions 2* lies on the open prairie near Okotoks. The surface underlying this erratic is different in composition and it is thought that a glacier carried the huge boulder to this site possibly from an area near Mount Edith Cavell in Jasper National Park. Other examples of evidence of glaciers in Alberta include hummocky moraines and eskers as shown in the photographs that follow. Hummocky moraines can be seen northwest of Calgary. Eskers can be seen along the Trans-Canada Highway near Seebe (west of Calgary).

HUMMOCKY MORAINE COURTESY OF RON MONROE

Hummocky moraines are knolls and mounds formed by debris collecting in faster melting parts of a retreating glacier.

AN ESKER COURTESY OF DR. GERALD OSBORN

Eskers are long ridges thought to have formed from deposition of sediments by subglacial streams.

VISIONS

The hilly terrain northeast of Drumheller is believed to have been formed by glaciers. Glaciers also provided this province with some valuable resources. Read pages 90 to 92 of your textbook to find answers to questions 18 to 21.

18. Study Figure 3.4 on page 91 of your textbook. What evidence leads scientists to suggest that Alberta was the meeting place for two glaciers?

19. Describe some of the geological features created by glaciers that are discussed in this reading selection.

20. Besides a scenic landscape, glaciers have left Alberta a number of important resources. Cite an example of one of these resources and explain in what way glaciers are responsible for this resource.

21. Describe how glaciers are responsible for Canada's drainage pattern.

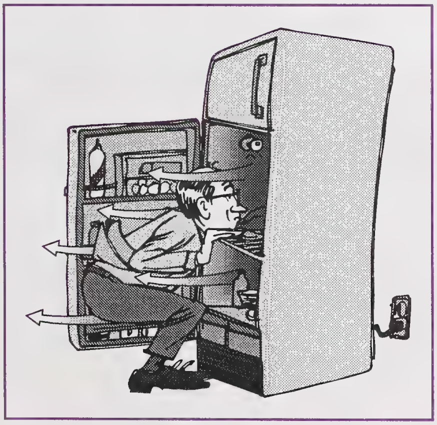
Check your answers by turning to the Appendix, Section 3: Activity 1.

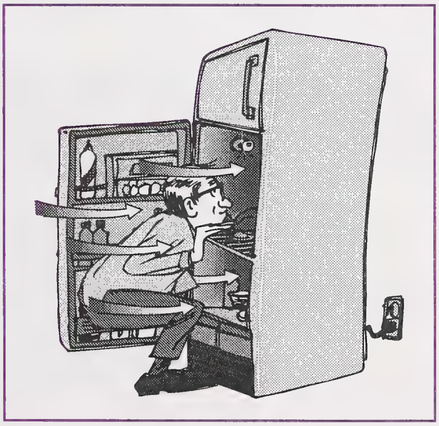
Activity 1 introduced you to a number of the landforms created by glaciers and has shown you how a knowledge of glaciation helps geologists read the land to decipher its geologic history. Activity 2 will provide evidence of other periods of glaciation and present you with a theory to explain them.

Activity 2: Clues to the Past

Activity 1 has shown you what effect glaciers have on land. As you work through Activity 2, you will discover that the Earth's surface was not the only factor altered by these vast sheets of ice. The climate too was affected.

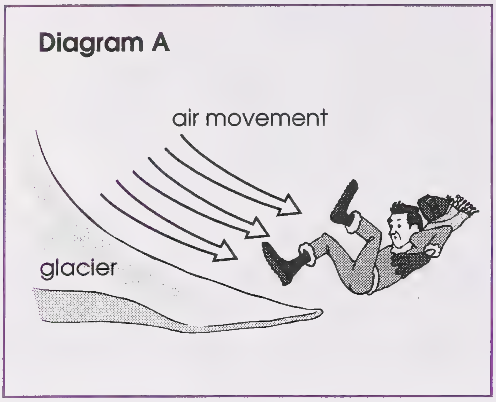
Study the following cartoon. Which scenario is true?

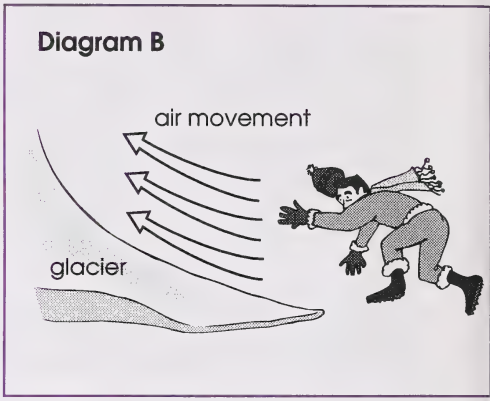




1. Why is it that when you open a refrigerator door, you feel the cold air rush out? Why doesn't the warm air rush in instead?

2. Just as the temperature of a room is affected by an open refrigerator, so too is the climate of an area around a glacier affected by the glacier. Which diagram do you think is the true scenario?





Glacial Periods and Climate

VISIONS

Advancing glaciers brought with them the ice ages – not once, but several times in the last three million years. Read pages 92 to 94 of your textbook to discover more about these glacial periods and their affect on the climate. Use this information to answer questions 3 to 8.

3. Explain the cause of the glacial high pressure and describe its effect on the movement of air over the adjacent terrain.

4. Describe what is meant by the term *ice age*.

5. According to the latest theories, how many ice ages have come and gone in the last three million years?

interglacial period – time between ice ages

6. Approximately how many years ago do scientists believe the present **interglacial period** began?

7. Explain how each of the following provide evidence for repeated periods of glaciation.

   a. land formations

   b. proportion of ${}^{18}_{8}O$ to ${}^{16}_{8}O$ in shells

   c. changes in sea level

VISIONS

8. On page 94 of your textbook you read that scientists estimate that, at some time in the past, the sea level was about 130 m lower than it is today. This occurred at a time when glaciation was at a maximum. How much do scientists estimate the sea level will rise if all of our present glacial ice melted? What effect might this have on the Earth as we know it?

Check your answers by turning to the Appendix, Section 3: Activity 2.

Causes of Glacial Periods

VISIONS

With the accumulation of evidence supporting the reoccurrence of ice ages, scientists began to look for patterns and reasons. Read pages 94 to 97 of your textbook to find out what was discovered. Summarize this information by completing questions 9 to 14.

9. The discoveries of many scientists led to the current theory used to explain the periodic reoccurrence of the ice ages. Indicate the contributions made by each of the following scientists: Alphonse Adhemar, Johann Kepler, James Croll, and Milutin Milankovitch.

positive feedback – feedback in which the outcome of an action reinforces the action

10. Explain how the idea proposed by James Croll is an example of a **positive feedback** system.

11. List the three variations in the geometry of the Earth's orbit that alter the amount of solar energy received by Earth.

12. Use a diagram to illustrate the position of the Earth in relation to the sun which scientists theorize would trigger an ice age for the northern hemisphere.

13. What is CLIMAP and how did it lend support to Milankovitch's theory?

14. Do you think it is important to study the glacial record? Why, or why not? State reasons and examples to support your opinion.

Check your answers by turning to the Appendix, Section 3: Activity 2.

Activity 2 has illustrated how changes to the Earth's orbit around the sun and its orientation in space can bring about large scale changes to the Earth's climate. Activity 3 will allow you to examine other factors that cause Earth's climate to be far from stable.

Activity 3: Global Warming and Glaciers

Earth's Climate Changes

VISIONS

The Earth's climate has not been stable. You have discovered that the surface of the Earth has provided evidence to suggest that its climate has gone through cyclic changes of cooling and warming. To review the type of evidence and the extent of the changes, read pages 97 and 98 of your textbook; then answer questions 1 to 3.

1. Describe how each of the following can provide information about Earth's past climate.

   a. Athabasca tar sands b. plant and animal fossils c. glacial terrain

2. What is believed to be the average temperature difference between past ice ages and the warmer, interglacial periods?

3. Select the best choice. The natural pace for climate change is measured in (tens, hundreds, thousands, millions) of years.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Effect of Humans on Global Climate

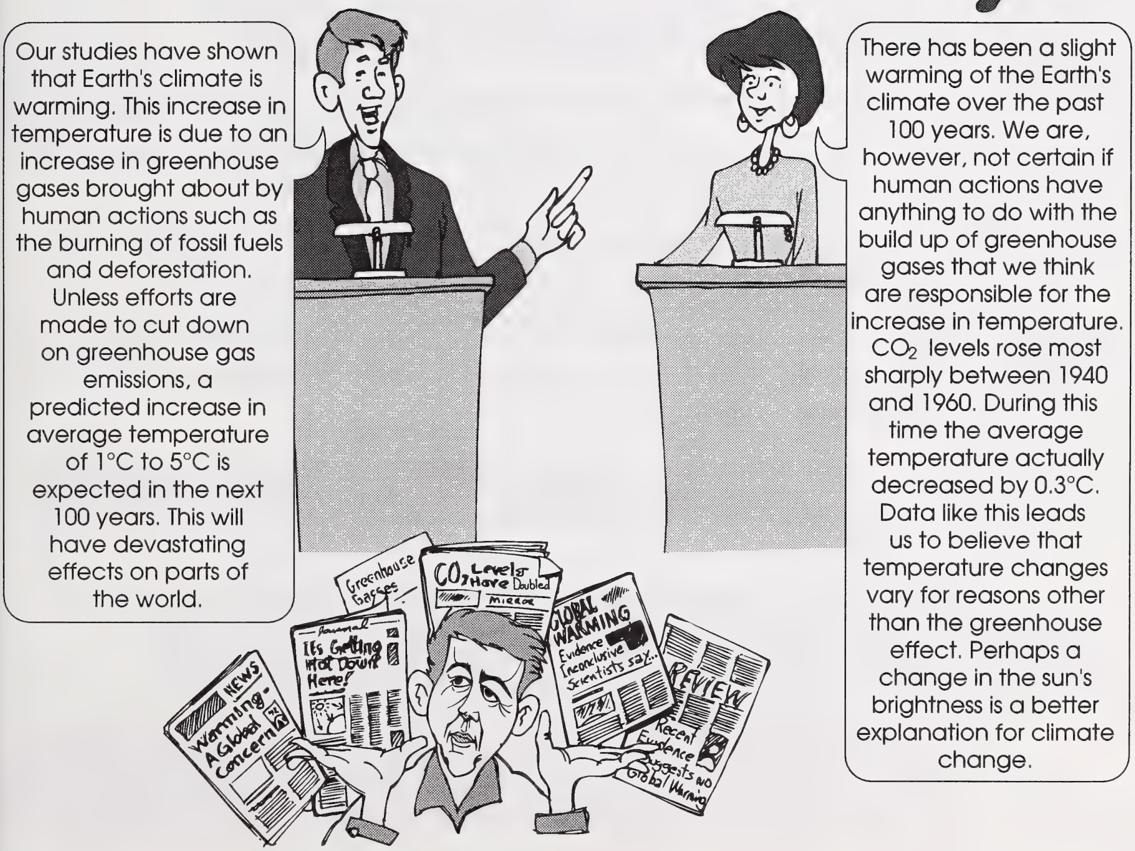
It's difficult to pick up a newspaper or a magazine these days without reading something about our changing climate. Why all this attention and concern? After all, hasn't Earth's climate gone through cycles of warming and cooling throughout its geological history? So why all this interest about a seemingly normal event?

4. Explain why you think there is a growing concern about climate change.

Check your answers by turning to the Appendix, Section 3: Activity 3.

People understood their critical dependence on climate long ago, and have worked to understand its underlying causes. So many variable factors impact on climate, however, that understanding it and predicting possible changes remains a puzzle.

Decades of scientific investigation, modeling, and computer simulations have left scientists arguing over interpretations.



If this type of disagreement among experts leaves you confused, you are not alone. After all, society depends on science for explanations and solutions. Disagreement on such a vital issue is alarming. So how do you sort things out? How do you decide if you should take action to deter global warming; or if you should consider the present warming trend as part of a natural cycle?

As with any decision, a good place to begin is by clearly stating the problem requiring a decision.

Science Skills

- ☑ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

5. Write, in the form of a question, a problem statement regarding global warming.

Check your answers by turning to the Appendix, Section 3: Activity 3.

VISIONS

The next step in examining this issue will be to collect information on which to base your decision. Begin by reading the section titled Changes in the Atmosphere Could Cause Climate Change on pages 98 to 100 of your textbook. Summarize the information presented by answering questions 6 to 9.

6. Explain each of the following statements:

   a. The greenhouse effect makes Earth habitable to countless forms of life.

   b. There is grave concern that the greenhouse effect will lead to catastrophic global warming.

7. List four significant greenhouse gases. Explain why CO_2 is expected to have the greatest effect on climate.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

8. CO_2 in the atmosphere is thought to come from natural and artificial sources. Copy the following chart; then summarize the information regarding sources of CO_2 by completing the chart.

Natural Sources of CO_2	Artificial Sources of CO_2

9. Explain how CO_2 is naturally removed from the atmosphere.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Research the topic of global warming through your local library. Use any recent books, magazine articles, or newspaper articles to find as much information as you can on the topic of global warming. Use this information to answer questions 10 and 11.

Science Skills

- ❐ A. Initiating
- ❐ B. Collecting
- ☑ C. Organizing
- ❐ D. Analysing
- ❐ E. Synthesizing
- ❐ F. Evaluating

10. Summarize what you have learned by completing the following chart.

What Is Known About Climate Change	What Is Thought to Be Known About Climate Change

Reread the problem stated in question 5, then answer question 11.

Science Skills

- ❐ A. Initiating
- ❐ B. Collecting
- ❐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

11. Copy and complete the following chart by providing positive and negative consequences for each alternative suggested. You must supply a third alternative.

Alternative	Consequences
maintain status quo; do nothing about global warming – let nature take its course	Positive
	Negative
change lifestyle to cut down on greenhouse gas emissions	Positive
	Negative
	Positive
	Negative

Check your answers by turning to the Appendix, Section 3: Activity 3.

VISIONS

Science Skills
☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☑ D. Analysing
☑ E. Synthesizing
☑ F. Evaluating

Ways to Slow Global Warming

Read the section titled Numerous Policies Are Aimed at Slowing Global Warming on pages 103 and 104 of your textbook. Use the information presented to answer question 12.

12. Copy and complete the following chart to summarize the information about different strategies aimed at addressing global warming.

Strategy	Examples	Positive and Negative Consequences
Engineering Countermeasures		
Adaptive Strategies		
Mitigation Strategies		

Consider all of the information you have gathered in this activity; then answer questions 13 and 14.

Science Skills
☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☐ D. Analysing
☑ E. Synthesizing
☐ F. Evaluating

13. State what you have decided on the issue of global warming. Explain your decision.

14. Outline actions you can take now that will support your decision.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Changes of the Earth's climate through its geological history brought on periods when great sheets of ice covered most of the land and periods of warming during which most of the ice melted. These repeating cycles of ice ages and interglacial periods helped shape the land.

1. Some topographical features thought to be the result of glaciation are listed in Column A. Match these with the correct description from Column B.

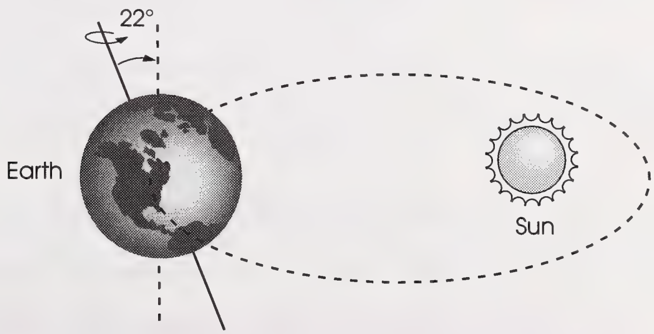
Column A	Column B
______ a. moraine	i. terraces made of fine glacial material deposited by glacial meltwater
______ b. U-shaped valley	ii. horseshoe-shaped basin formed at the head of a glacier by ice plucking and undercutting high peaks and ridges
______ c. cirque	iii. body of material carried along and ultimately deposited when the ice melts
______ d. striations	iv. valley with steep walls and a flat floor formed as ice flows down a valley, scraping and rounding off irregularities
______ e. outwash plains	v. parallel scratches and grooves in rock formed when rocks embedded in glacial ice scrape across the Earth's surface

2. Describe three features of Alberta's landscape directly related to past glacial action.

3. Give examples of evidence for repeated periods of glaciation gained from each of the following sciences.

   a. paleontology   b. oceanography   c. geology

4. The following diagram illustrates the position of the Earth in relation to the sun, which scientists theorize will trigger an ice age for the northern hemisphere. Describe the three features of the geometry of Earth's orbit that represent the least amount of solar energy received by the northern hemisphere.



5. Describe the contribution of ice core sampling to an understanding of climate change.

6. Explain what is suspected to be the main contributor to the build up of CO_2 in the atmosphere.

VISIONS

7. Do question 10 on page 110 of your textbook.

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

Complete two of the following.

1. Research what is meant by the following terms used to describe various glacial landforms. Explain how each was formed.

   a. drumlin
   b. horn
   c. hanging valley
   d. hummocky moraine
   e. esker

2. Compose an essay relating to the idea that individuals can or cannot significantly influence governments and industries to seriously deal with the possibility of major climate change in the future.

VISIONS

3. Read the section titled Careers in Geoscience on pages 105 to 107 of your textbook; then summarize the information presented by answering questions a. to c.

   a. What is *Lithoprobe*?

   b. To learn what each of the following scientists do, make and complete a chart like the following.

Type of Scientist	Example of an Area of Investigation
geophysicist	
seismologist	
geologist	
geochemist	
geochronomist	

   c. What insights do the scientists of Lithoprobe hope to gain by their investigations?

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

Section 3 allowed you to examine climate changes and their effect on the Earth's surface. In Activity 1 you were able to study the role of glaciers in forming the land; in Activity 2 you explored a theory to explain the reoccurrence of ice ages; and in Activity 3 you examined the effect of changes in the composition of the atmosphere on climate. The possibility of global warming and its probable effects on the Earth's surface were also examined.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 3.

MODULE SUMMARY

The Earth's surface is dynamic – ever changing. Some changes are sudden such as those brought on by earthquakes and volcanoes. Other changes are gradual such as those resulting from the tectonic movement of crustal plates and the cyclic changes of climate. Evidence of these changes abounds. It can be found in topographic features of an area, in fossil remains locked up in rock layers, and frozen in glacial ice.

The search for knowledge about the Earth's changing surface provides much information and has led to the development of technologies which allow scientists to map, sample, test, experiment, and model the Earth's features; thus, a clearer understanding of the Earth's structure, age, and history are brought about. This knowledge of the Earth has helped scientists to develop theories to explain past events and understand present changes. Seismic studies, undertaken to understand earthquakes, has led to theories about the Earth's interior. The theory of plate tectonics is used to explain both the violent and the gradual changes on the Earth's surface. Theories related to the Earth's orbit around the sun are used to explain cyclic climate changes.

Unfortunately scientific knowledge about geologic processes is not complete. Many questions remain. Scientists use their theories to make predictions about future changes to the Earth and its climate. The validity of these predictions will be the test for these theories.

In Module 2 you will continue your discoveries of dynamic Earth. You will discover the interdependence of changes in the living and non-living components of the Earth, and learn about the fossil evidence that has led to different theories of evolution illustrating this interdependence.

Appendix

- Glossary
- Science Skills
- Suggested Answers

Glossary

amplitude: half the distance between a wave crest and a wave trough

asthenosphere: a partially molten layer of the Earth's upper mantle (100 km to 250 km deep)

body waves: seismic waves that travel through the interior of the Earth

convection: the circulation of a substance driven by temperature and density differences within that substance

core: the central zone of the Earth made up of an outer liquid region and an inner solid region

crest: the high point of a wave

crust: the outer layer of the Earth's surface

earthquake magnitude: the amount of energy released at the point of origin of an earthquake

elastic rebound: the ability of a material to return to its original shape after stress has been applied

epicentre: the point on the Earth's surface directly above the focus of an earthquake

focus: the point of origin of an earthquake

fossil: any preserved evidence of past animal- or plant-like class

frequency: the number of wave crests that pass a fixed point during a specific time interval

inertia: the tendency of a body at rest to remain at rest and a body in motion to remain in motion

interglacial period: time between ice ages

lithosphere: the rigid outer shell of the Earth made up of continental and oceanic crust

longitudinal wave: an energy wave in which the particles of matter vibrate parallel to the direction of energy propagation

L-waves: surface seismic waves that arrive at a seismic station last

mantle: a thick layer of the Earth that separates the crust from the core that is responsible for convection currents which affects the crust

mesosphere: the solid region of the Earth's mantle lying between the asthenosphere and the outer core

Moho: the boundary between the Earth's crust and upper mantle

period: the interval of time between the arrival of wave crests

positive feedback: feedback in which the outcome of an action reinforces the action

P-waves: the first seismic waves to reach a seismic station (longitudinal waves)

seismic gap: areas along plate margins where no earthquake activity is occurring

seismic station: a place where technology is employed to collect seismic data

seismic wave: a shock wave produced by vibrations

seismogram: the record of seismic data collected by a seismograph

seismograph: a device attached to a seismometer that produces a record of seismic activity

seismologist: a scientist who studies earthquakes and the Earth's crustal movement

seismology: the study of earthquakes and the Earth's crustal movement

siesmometer: an instrument that collects evidence of seismic activity

surface waves: seismic waves that travel along the surface of the Earth

S-waves: transverse, seismic waves arriving at a seismic station after the P-waves

transverse wave: an energy wave in which the particles of matter vibrate perpendicular to the direction of energy propagation

wavelength: the distance between identical points on successive waves

Science Skills

A Framework For Scientific Problem-Solving Skills

A. Initiating and Planning	• identify and clearly state the problem or issue to be investigated • differentiate between relevant and irrelevant data or information • assemble and record background information • identify all variables and controls • identify materials and apparatus required • formulate questions, hypotheses and/or predictions to guide research • design and/or describe a plan for research or to solve the problem • prepare required observation charts or diagrams
B. Collecting and Recording	• carry out and modify the procedure if necessary • organize and correctly use apparatus and materials to collect reliable experimental data • accurately observe, gather and record information or data according to safety regulations (e.g., WHMIS) and environmental considerations
C. Organizing and Communicating	• organize and present data in a concise and effective form (themes, groups, tables, graphs, flow charts, and Venn diagrams) • communicate data more effectively, using mathematical and statistical calculations where necessary • express measured and calculated quantities to the appropriate number of significant digits and use appropriate SI units for all quantities

. Analysing

- analyse data and information for trends, patterns, relationships, reliability, and accuracy
- identify and discuss sources of error and their effect on results
- identify assumptions, attributes, bias, claims, or reasons
- identify main ideas

Connecting, Synthesizing, and Integrating

- predict from data or information
- formulate further testable hypotheses supported by the knowledge and understanding generated
- identify alternatives for consideration
- propose and explain interpretations or conclusions
- develop theoretical explanations
- relate the data to laws, principles, models, or theories identified in background information
- answer the problem investigated
- summarize and communicate finding
- decide on a course of action

Evaluating the Process or Outcomes

- establish criteria to judge data or information
- consider consequences and perspectives
- identify limitation of the data, and information, interpretations, or conclusions as a result of the experimental/research/project/design, processes, or methods used
- suggest alternatives and consider improvements to experimental technique and design
- evaluate and assess ideas, information, and alternatives

CRITERIA FOR ASSESSING SCIENTIFIC PROBLEM-SOLVING SKILLS

A. Initiating and Planning

Level 1	Level 2	Level 3	Level 4
• Proposes a simple problem statement when initiated to do so	• Proposes a simple problem statement	• Proposes a problem to be investigated	• Clearly states the purposes and problem to be investigated
• Background information must be supplied	• Background information is supplied from teacher or student's own experience	• Background supplied by teacher, reference material, or student's own experience	• Prepares the necessary background information from references, research, discussion, and/or past experience
• Identifies those things that change and those that stay the same	• Identifies variables and controls	• Identifies controls, manipulated variables, and responding variables	• Identifies the controls and variables
• Guesses about the outcomes	• Makes 'educated' guesses	• Makes a prediction and/or suggests a simple hypothesis	• Forms an appropriate hypothesis and prediction • Designs an investigation
• Identifies simple materials and equipment to be used	• Identifies materials and equipment to be used • Is able to assemble simple apparatus	• Identifies the materials and equipment to be used • Assembles simple apparatus	• Identifies and names the materials and equipment to be used • Assembles and designs or modifies simple apparatus
• Follows directions as provided	• Follows directions as provided • Is able to write simple procedural statements	• Develops and organizes a simple written procedure	• Designs and writes descriptions of procedures that are clear and detailed
	• Prepares observation charts, tables, and diagrams as directed by teacher	• Prepares observation charts, tables, diagrams, graphs • Performs calculations as outlined by teacher	• Prepares observation charts, diagrams, and graphs • Performs necessary calculations

B. Collecting and Recording

Level 1	Level 2	Level 3	Level 4
• Follows a simple procedure	• Follows a simple procedure	• Follows a given procedure and is able to suggest modifications when asked to do so	• Follows a given procedure and modifies the procedure when necessary
• Correctly uses apparatus and materials as directed by teacher	• Correctly uses apparatus and materials with little teacher assistance	• Correctly uses apparatus and materials with infrequent modification	• Consistently uses standard apparatus and materials correctly
• Collects data using concrete, tangible objects	• Collects tangible objects • Carries out simple measurements	• Accurately collects data	• Accurately collects relevant data
• Records data in sentence form or in simple charts that have been constructed	• Records data in numerical and non-numerical form • Is able to use and construct simple charts	• Records relevant data including the correct units with respect to measured data	• Records relevant data using the appropriate units
• Is aware of safety and environmental concerns • Follows stated safety procedures	• Is aware of safety and environmental concerns • Follows stated safety procedures	• Shows appropriate safety and environmental concerns in the use, care, and maintenance of materials and apparatus	• Demonstrates appropriate standards of safety
		• Is able to locate appropriate safety regulations • Actively participates in teacher-directed discussion of safety and environmental issues	• Is able to suggest modifications to procedures to minimize environmental damage

C. Organizing and Communicating

Level 1	Level 2	Level 3	Level 4
• Organizes data in sets of concrete objects	• Organizes data in sets of objects	• Organizes data in the form of sets, themes, and/or tables	• Organizes data accurately
	• Provides a basis for the organization of data sets • Constructs simple graphs to represent the data	• Provides a basis for and suggests alternatives for the organization of data • Is able to construct graphs and/or tables to represent the data	• Is able to represent data using appropriate graphs and tables
	• Performs basic mathematical calculations	• Performs basic mathematical calculations	• Performs relevant and required mathematical calculations
	• Identifies, with teacher assistance, errors and inaccuracies	• Identifies errors and discrepancies in data • Takes part in teacher-directed discussion of scientific inaccuracies	• Expresses measured and calculated quantities to correct degree of precision

D. Analysing

Level 1	Level 2	Level 3	Level 4
• Correctly identifies patterns within the data	• Assesses patterns and trends that are conceptually presented by the data	• Assesses patterns, trends, and simple relationships	• Assesses patterns, trends, and relationships resulting from collected and manipulated data
• Identifies, with teacher assistance, relationships	• Identifies simple cause and effect relationships	• Identifies cause and effect relationships	• Identifies the sources of error in data collection and manipulation
	• Identifies, with teacher assistance, the sources of error in data collection and manipulation	• Identifies the sources of error in data collection and manipulation	• Expresses accuracy qualitatively and/or quantitatively (percent difference), where applicable • Identifies the assumptions relating to measurement and/or analysis
	• Identifies, with teacher assistance, the effect of errors on results	• Suggests amendments to procedures and/or data manipulation in order to rectify results	• Determines the reliability of the data

E. Connecting, Synthesizing, and Integrating

Level 1	Level 2	Level 3	Level 4
• Provides a simple but not necessarily appropriate answer to the problem investigated based on results obtained	• Provides a simple answer that is appropriate for the problem investigated and results obtained	• Provides an appropriate answer to the problem investigated based on results obtained	• Provides a qualified answer to the problem investigated
	• Attempts to relate results to knowledge that is not specifically related to scientific theories or laws	• Relates results, with teacher assistance, to applicable theories and/or laws	• Relates the data to laws, principles, models, or theories identified in background information and/or in broader context
			• Proposes and explains interpretations or conclusions • Develops theoretical explanations

F. Evaluating Progress or Outcomes

Level 1	Level 2	Level 3	Level 4	Level 5
• Attempts to explain results to the problem investigated	• Attempts to explain results to the problem investigated	• Is able to explain the results obtained in light of the problem being investigated	• Evaluates the prediction and concepts	• Restricts, revises, or replaces an unacceptable scientific concept
	• Attempts to draw conclusions where applicable and when prompted	• Draws conclusions and attempts to explain them	• Draws conclusions and attempts to explain them	• Establishes criteria to judge the design, prediction, and concepts
		• Discusses the limitations of the data collected, interpretations, and/or conclusions	• Identifies limitations of the data and information, interpretations, or conclusions, as a result of the design of the experiment, research, or project	• Considers consequences and perspectives • Evaluates assumptions and effects of bias
		• Discusses, when prompted, the validity of results • Discusses, when prompted, alternatives and/or improvements to the experimental design	• Suggests alternatives and considers improvements to experimental technique and design	• Evaluates the total investigation in terms of reliability and validity

SKILL ASSESSMENT RECORD															
Feedback from Assignments			Initiating and Planning		Collecting and Recording		Organizing and Communicating		Analysing		Synthesizing and Integrating		Evaluating	
Module	Section	Question	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teache
1														
2														
3														
4														
5														
6														
7														
8														

Suggested Answers

Section 1: Activity 1

1. The young people are practising skill B – Collecting and Recording. They probably also practised skill A, Initiating and Planning, before going on their field trip to the pond.

2. The students in the laboratory are organizing and communicating – skill C.

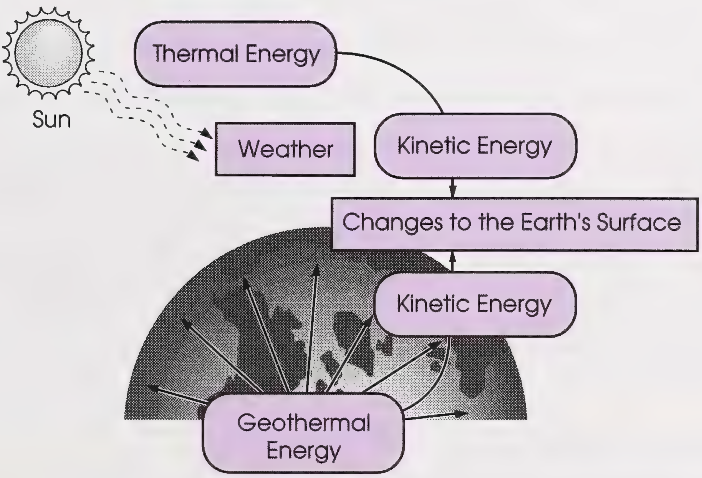
3. The scientist may be connecting, synthesizing, and integrating data – skill E. He may also be performing skill F – Evaluating progress or outcomes. These skills used for more extensive experiments are in addition to the basic skills used.

Section 1: Activity 2

1.

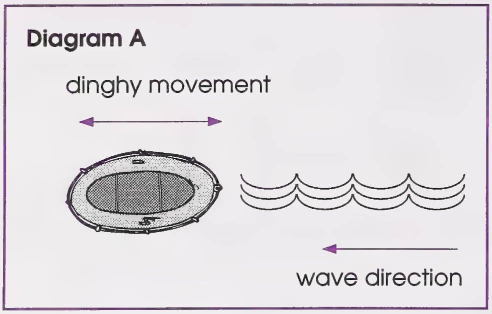
Sudden Changes		Gradual Changes	
• earthquakes • avalanches • volcanoes	• hurricanes • tornadoes • floods	• mountain formation • shoreline changes • changing course of rivers and streams	• soil formation • erosion • river delta formation

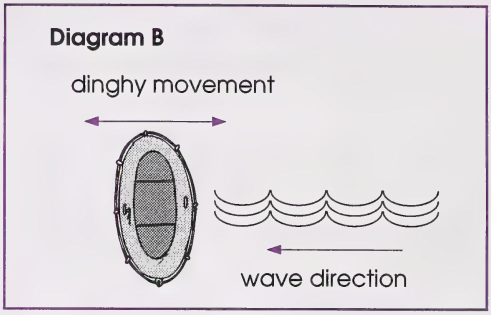
2. a. Scientists have confirmed that the interior of the Earth is hot. They have theorized that this geothermal energy changes to kinetic energy, which helps to reshape the Earth's surface. The Earth also receives a lot of thermal energy in the form of solar radiation. This energy is converted to the kinetic energy of weather. The following diagram illustrates this conversion of energy.



b. The kinetic energy acting on the Earth's surface can take the form of earthquakes, volcanoes, tornadoes, mountain formation, erosion, and so on.

3. You would feel yourself move up and down. Then, depending on which side of the dinghy was pointed into the waves, you would also feel either a back and forth movement (as in Diagram A) or a side-to-side rocking movement (as in Diagram B).





4. The container bobs up and down and rocks from side to side.

5. A water wave moves up and down and back and forth. A seismic wave moves the ground the same way.

6. The purpose of the investigation is to gain an understanding of seismic waves by using models to simulate wave motion.

7. Your steps should be something like the following.

Part A

Step 1: Tie a couple of coils at each end of the Slinky® to a chair. Elastic bands work well to secure the coils to the chair.

Step 2: Move the chairs far enough apart so most of the coils are pulled apart slightly. (If you are using a table, place the chairs at the ends of the table.)

Step 3: Put a piece of masking tape around one coil near the middle of the Slinky®.

Step 4: Place a piece of masking tape on the floor or on the table under the taped coil.

Step 5: Bunch the coils from about one quarter of the Slinky® at one end, then release the bunched up coils.

Step 6: Observe the motions of the Slinky® as the wave travels back and forth. Repeat several times if necessary.

Step 7: Record the time it takes the wave to travel away from and back to its starting point. Use the audiotape with recorded timing intervals as a timing device, or you may try counting 1001, 1002, 1003 and so on to approximate seconds. Compare the time to that in Part B and record an answer relative to the time you observed in Part B.

Part B

Step 1: Use the same setup as in Part A.

Step 2: Pull the Slinky® to one side near one end and release. Observe the wave that is created.

Step 3: Record the time it takes the wave to travel to the other chair and back to its starting point. Record an answer relative to the time you observed in Part A.

8. The controlled variables are as follows:

Part A

- type of Slinky®
- starting position of Slinky®
- where the tape is placed on the Slinky®
- surface on which Slinky® moves
- amount of Slinky® released to generate the wave
- timing device

Part B

You should have the same variables as in Part A except Step 5. In Part B, the displacement of the Slinky® in Step 5 of the procedure in *Visions 2* should be constant during all trials.

9. Predictions may vary. You should make predictions for each of the following points for both Part A and Part B.

- movement of tape on coil relative to the tape on the floor
- position of tape on coil relative to tape on floor after the coil comes to rest
- appearance of the coils as the wave travels through them
- the time it takes for the wave to travel to the other chair and back to its point of propagation
- direction the wave travels in relation to the Slinky®

0. Answers may vary. Your chart may look something like the following.

Part	MOVEMENT OF TAPE ON COIL		Appearance of Coils	Direction of Motion	Time
	Relative to Tape on Floor	Position of Tape When It Comes to Rest			
A					
B					

1. Answers will vary. See the following table for sample data.

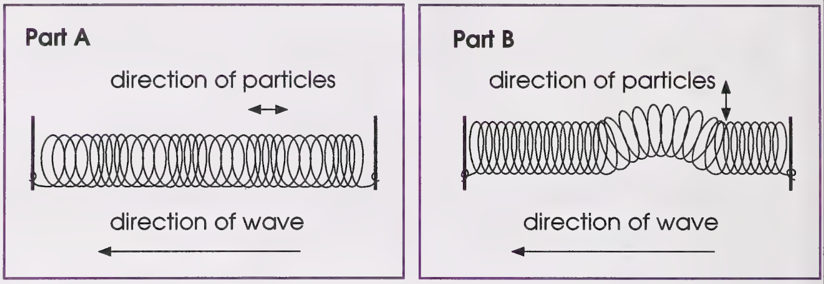
Part	MOVEMENT OF TAPE ON COIL		Appearance of Coils	Direction of Motion	Time
	Relative to Tape on Floor	Position of Tape When It Comes to Rest			
A	forward then back	approximately the same as at the start	coils ahead of wave are compressed, and coils behind wave are expanded	parallel to Slinky®	faster than Part B
B	sideways, away from then towards	approximately the same as at the start	coils expand on outside of wave and compress on inside of wave	perpendicular to Slinky®	slower than Part A

12. **Textbook question 1:** The energy to move the Slinky® came from the chemical energy of food eaten by the person setting the wave in motion.

    Textbook question 2: Energy was transferred along the Slinky® by wave motion. In Part A, the particles of matter in the coils of the Slinky® vibrated back and forth, parallel to the direction of energy propagation. In Part B, the particles of matter in the coils of the Slinky® moved sideways, perpendicular to the direction of energy propagation.

    Textbook question 3: The wave in Part A travelled faster because it has a smaller distance to move in the compressions and expansions than the distance required to move in the undulating motion of the Slinky® in Part B.

13. The wave generated in Part A was a longitudinal wave since the particles of matter moved parallel to the direction of the wave. The wave generated in Part B was a transverse wave since the particles of matter moved perpendicular to the direction of the wave.



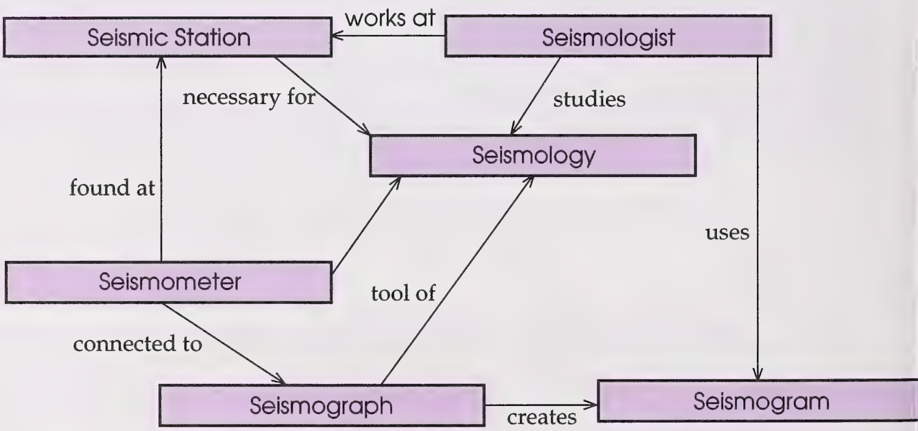
14. Answers may vary. One possible description is as follows:

    Kinetic energy released from the sudden slipping of a fault near the Earth's surface may cause an earthquake. The energy of the earthquake travels as seismic waves, both longitudinal and transverse, through the Earth and along its surface. The ground responds to these waves by alternately compressing and expanding and moving up and down. These ground motions can set up vibrations in the house that may cause it to collapse.

15. Forces within the Earth can put rock layers under stress similar to those experienced by the piece of wood that is bent until it breaks in Figure 1.4. The wood breaks when the stress placed on it exceeds its elastic limit (ability to bend). Rock layers behave the same way, and just as the two pieces of broken wood rebound to their original straight shape, so too do the rock layers.

Section 1: Activity 3

1. Answers may vary.



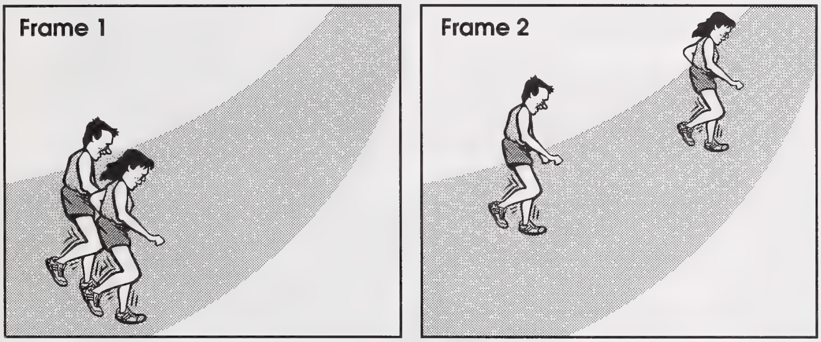
2. Answers may vary. The epicentre is the place on the Earth's surface directly above the origin of the earthquake called the focus, which lies below the Earth's surface.

3.
- seismic waves
  - body waves
    - P-waves
    - S-waves
  - surface waves
    - L-waves

4. The particles of matter in a P-wave move parallel to the direction of the wave; therefore, a P-wave is a longitudinal wave. The particles of matter in an S-wave move perpendicular to the motion of the wave; therefore, an S-wave is a transverse wave.

5. More than one seismograph is required to cover the wide range of ground movement. One may measure the vertical ground movement and the others may measure the horizontal ground movement. Different seismographs are also required to respond to waves of varying periods.

6. The principle of inertia states that an object at rest will tend to stay at rest. The more mass an object has, the more its inertia. The seismograph is based on this principle because as seismic waves cause its frame to move, the mass will not move because of its inertia. This allows the pen to trace out the difference in motion between the ground and the mass.

7.


8. The difference in arrival times are as follows:

Station A: $S - P = 20\ s - 0\ s = 20\ s$

Station B: $S - P = 10\ s - 0\ s = 10\ s$

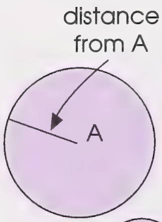
Station C: $S - P = 30\ s - 0\ s = 30\ s$

Station C is farthest from the earthquake since the $S - P$ is greatest.

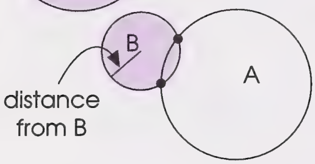
9. The distances of each station from the epicentre of the earthquake are as follows:

Seismic Station	S – P (s)	Distance from Epicentre (km)
A	20	170
B	10	86
C	30	256

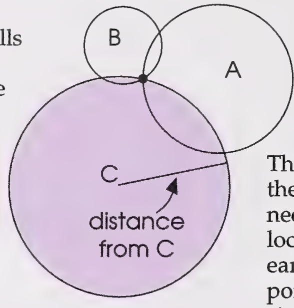
10.



The seismic data from the first station tells how far the earthquake was from that station, but not the direction. It could be anywhere around the circle



The seismic data from the second station narrows the possible location to two possible points where the circles intersect.



The seismic data from the third station is needed to pinpoint the location of the earthquake. This is the point where all three circles intersect.

11. The Richter scale determines the magnitude of an earthquake by the amount of ground motion and energy release

12. An earthquake that measures 6.5 on the Richter scale has 100 times the amount of ground motion than one tha measures 4.5 on the Richter scale.

13. The purpose of this investigation is to determine the magnitude and the epicentre of an earthquake from information given about a hypothetical earthquake.

14. a.

Station	Difference in S- and P-waves (s)	Distance from Epicentre (km)
Dawson Creek	22.4	187
Fort McMurray	42.8	367
Edmonton	44.8	384

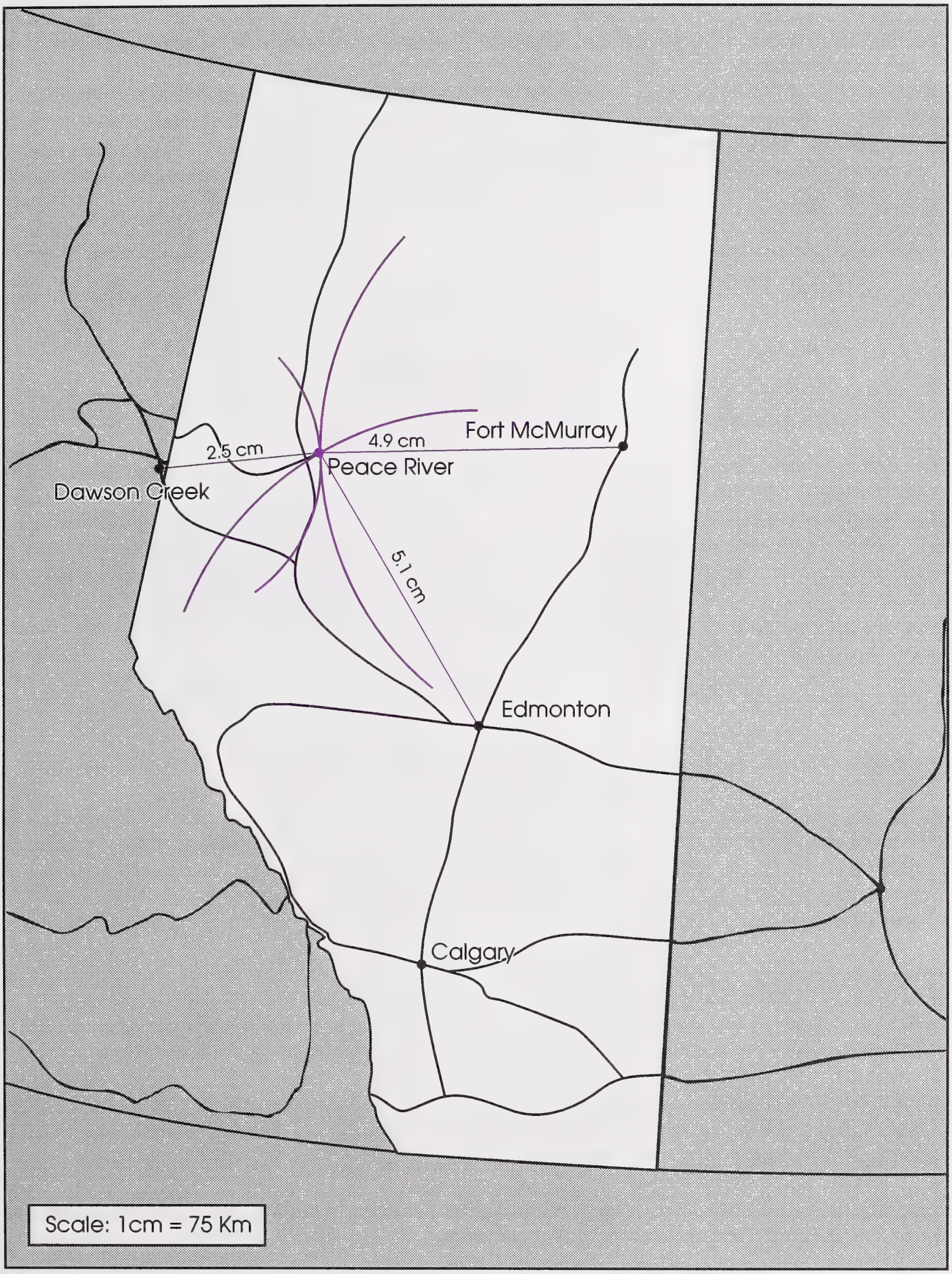
b.

Station	Distance on Map (cm)	Magnitude (nearest tenth)
Dawson Creek	2.5*	4.0
Fort McMurray	4.9*	3.8
Edmonton	5.1*	3.9

* Rounded to the nearest tenth of a centimetre.

c. The average magnitude is 3.9 (to the nearest tenth).

d.



15. **Textbook question 2:** Seismic data is collected from stations outside the area of damage to ensure accurate data and to safeguard expensive equipment and lives of investigators.

Textbook question 3: By using Greenwich mean time for calculations, corrections for different time zones are unnecessary.

Textbook question 4: You can use the distance from any station, divide the distance by the velocity of the P- or S-waves. This quotient is then subtracted from the arrival time given on Table 1.2 on page 12 of *Visions 2*. Then subtract 8 h to change to Mountain Standard Time. The earthquake took place at 19:42:05 MST.

For example, use the P-wave for Edmonton.

$$\begin{aligned} t &= \frac{d}{v} \\ &= \frac{384 \text{ km}}{6.2 \text{ km/s}} \\ &= 62 \text{ s} \ \left(2 \text{ significant digits}\right) \end{aligned}$$

$$\begin{aligned} 03:43:07 - 00:00:62 &= 03:42:67 - 00:00:62 \\ &= 03:42:05 \\ 03:42:05 - 08:00:00 &= 27:42:05 - 08:00:00 \\ &= 19:42:05 \end{aligned}$$

16. The location of an earthquake can be determined using seismograms of the earthquake from three different seismic stations. The first step is to calculate the difference in arrival times between S- and P-waves. This value can then be used to determine the distance of each seismic station from the epicentre of the earthquake. Three circles are then drawn on a map with radii corresponding to the distance between each station and the location of the earthquake. The point at which these three circles intersect determines the location of the earthquake. To determine the magnitude of the earthquake the amplitude of the seismic waves is measured and then plotted on a scale, so that a magnitude value can be determined (as shown in Figure 1.7 on page 13 of *Visions 2*).

Section 1: Activity 4

1. a. Seismic risk does not just refer to the chances of an earthquake occurring in an area, but more importantly how safe an area is when an earthquake does occur.

   b. The seismic risk of an area can be reduced by employing specialized construction techniques for both surface structures as well as underground pipelines. Another way to reduce seismic risk is to ensure that well-trained relief teams are always kept prepared for emergencies. It could also be recommended that structures not be constructed in certain areas such as fault lines.

2. Seismologists use seismic data and other information to assess the seismic risk of an area. Structural engineers then use this information when planning construction projects.

3. a. Three variables involved in predicting earthquakes are magnitude, location, and time.

   b. Of these three variables, time is the most difficult to predict because scientists don't yet understand the forces that cause stress on rock layers well enough; therefore, it is difficult to predict just when rock layers will exceed their elastic limit.

4. At present, scientists think they can predict the location and approximate magnitude of an earthquake, but are not able to predict the exact time that it may occur.

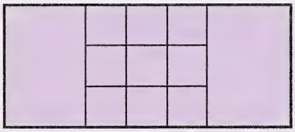
The purpose of the investigation is to use a model and investigate the motion of the ground at the surface of the Earth caused by seismic waves.

Predictions will vary but could be something like the following:

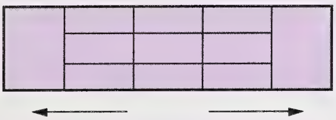
- The squares will be elongated to become rectangles when stretched and squeezed to become vertical rectangles when compressed.
- When bent upward in a U-shape, the upper rectangles will be squeezed while the lower ones are stretched. The opposite happens when the foam block is bent downward.

Your observations chart should look like the following.

Acetate Sheet A (Original Markings)

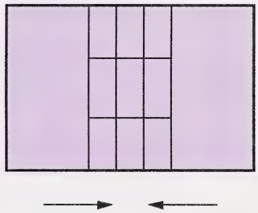


Acetate Sheet B (Stretched)



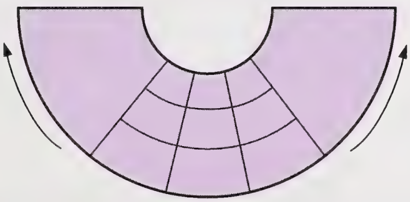
- shapes are rectangles
- shapes are longer than those on sheet A

Acetate Sheet C (Compressed)



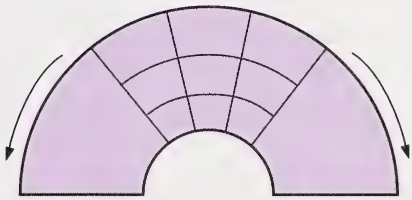
- shapes are shorter than those on sheet A
- shapes are rectangles

Acetate Sheet D_1 (Bent ∪)



- shapes are curved
- shapes on the upper part of the block are shorter
- shapes on the lower part of the block are longer

Acetate Sheet D_2 (Bent ∩)

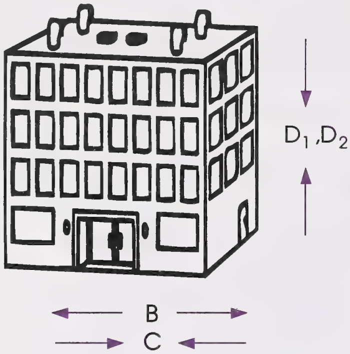


- shapes are curved
- shapes on the upper part of the block are longer
- shapes on the lower part of the block are shorter

8. **Textbook question 1:** Stretching and compressing the block simulates longitudinal or P-waves. Bending the block simulates transverse or S-waves.

   Textbook question 2: If you were standing on the part that is being stretched, you feel your legs pull apart. When compression occurs, your legs come back together. Bending the ground up and down would move you up and down.

   Textbook question 3:



   If the building is very large, then part of the building may move one way and another part may move a different way. Also, part of the building may move up while another part of it may move down.

   Textbook question 4: These forces may cause the building to collapse. Buildings can be made more earthquake-resistant by building them with wood and bracing them diagonally.

9. It would not be safe because all of the ornate carvings, columns, and balconies will shake loose during the earthquake and could fall.

10. You could make the exterior simpler by eliminating the carvings, the columns, and the balconies. When an earthquake does occur, there would be less chance of debris falling.

11. The side-to-side or longitudinal ground motion causes the greatest concern because it causes the greatest structural damage.

12. Tall buildings naturally sway in response to wind. If the building is already swaying when the earthquake hits, the effect of the earthquake-induced motion on the building can be amplified.

13. Two factors that help determine a building's ability to withstand damage are the material its made of and its size.

14. Liquefaction is the process by which water-saturated soil becomes fluid. When the soil becomes fluid, buildings can sink or tilt and fall down during an earthquake.

15. Answers will vary. Some examples are as follows:

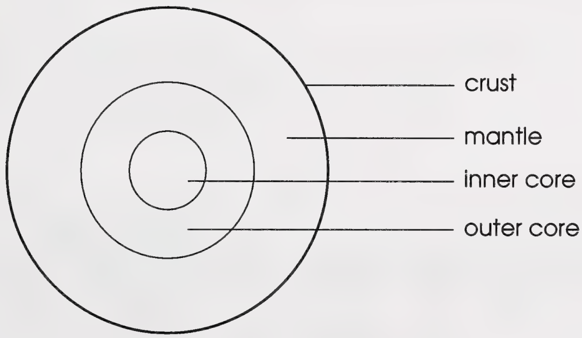
    - tall steel-frame buildings are made flexible so they can sway without breaking
    - use of a steel-reinforced concrete slab to keep buildings from sinking
    - use of fire-resistant drywall material to protect against fire
    - use of flexible natural gas lines
    - bolting heavy furniture down

Section 1: Activity 5

1.

Order	Discovery	Structure of the Earth's Interior
3	• prediction of the existence of the asthenosphere	• The upper mantle is partially molten.
1	• discovery of a shadow zone within the Earth	• Part of the Earth's core is liquid.
4	• proposition of a theory that divided the Earth's core into two zones	• The core has an outer liquid layer and a solid inner layer.
2	• discovery of the Moho boundary	• The Earth's crust has two thicknesses. It is thinner under oceans and thicker under the continents.

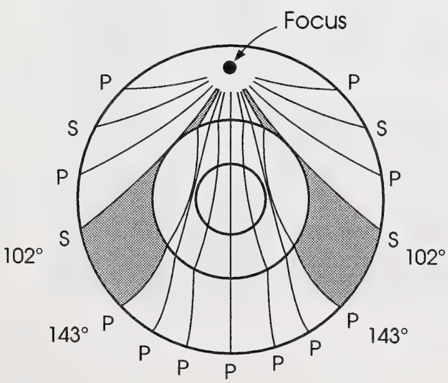
2.



3. P-waves are longitudinal, fast, and can move through a liquid and a solid.

S-waves are transverse, slower than P-waves, and can only travel through a solid.

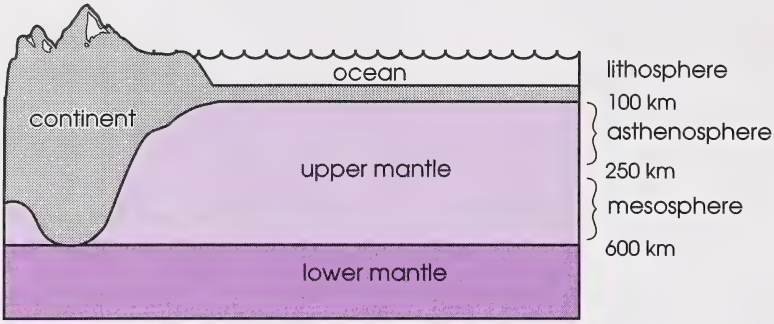
4.



5. Scientists gained indirect evidence through seismic data, magnetic data, and computer models.

6. Large machines were used to pound the ground, generating seismic waves. Data was collected and then analysed to see how the seismic waves were reflected and refracted as they passed through the Earth.

7. The lithosphere extends from the surface of the Earth to about 100 km below the surface. It is a rigid, cool zone. The asthenosphere is the area 100 km to 250 km below the Earth's surface. It is a partially molten, hot zone. The mesosphere is the area 250 km to 600 km below the Earth's surface. It is a hot, high pressure zone.



8. Superpress is a very large hydraulic press. It is used to squeeze matter with enough pressure to simulate conditions 800 km below the Earth's surface. Scientists are using it to try to understand more about the Earth's mantle – how it formed and what may happen in the future.

9. The solution to the crossword puzzle is as follows:

			1 A	M	P	L	I	T	U	D	2 E						
											P						
				3 W		4 S	E	I	S	M	I	C					
5 S	U	R	F	A	C	E					C						
				V		I			6 F	R	E	Q	U	E	N	C	Y
	7 R			E		S					N						
	I			S		8 M	A	G	N	I	T	U	D	9 E			
	C		10 S			O					R			L			
	H		E			L		11 P			E			A			
	T		I			O		W						S			
12 S	E	I	S	M	O	G	R	A	P	H				T			
	R		M			Y		V						I			
		13 B	O	D	Y			E				14 F	O	C	U	15 S	
			G													W	
		16 T	R	A	N	S	V	E	R	S	E					A	
			A													V	
			M													E	

Section 1: Follow-up Activities

Extra Help

1. Before the earthquake, forces are at work under the Earth's crust building up stress in rock layers. When this stress exceeds the elastic limit (ability to deform), the rock layers break creating a fault and causing an energy transfer as the rock layers vibrate. Some of the released energy travels through the ground as seismic waves. During the earthquake, the ground moves as the seismic waves pass through it. After this released energy dissipates, the earthquake is over and the Earth's surface is changed.

2.

Wave Type	Description of Wave Type
P-wave	• faster than S-waves • particles move in same direction as energy propagation
S-wave	• slower than P-waves • particles move in a perpendicular direction to the direction of energy propagation

3. a. Parkfield has many earthquakes.

   b. The main goal of the research is to understand earthquakes better so that someday researchers can predict when and where an earthquake will occur.

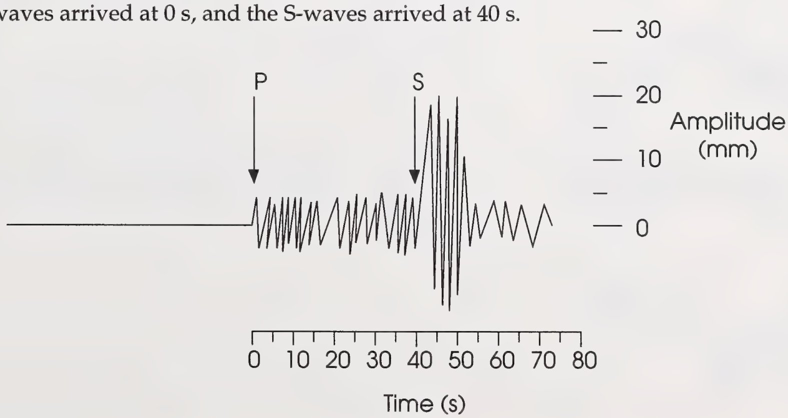
4. a. A seismometer is a device to which a seismograph can be attached to generate a seismogram (a record of ground motion).

   b. The magnitude or strength of an earthquake can be measured on the Richter scale to determine the amount of ground motion.

5.

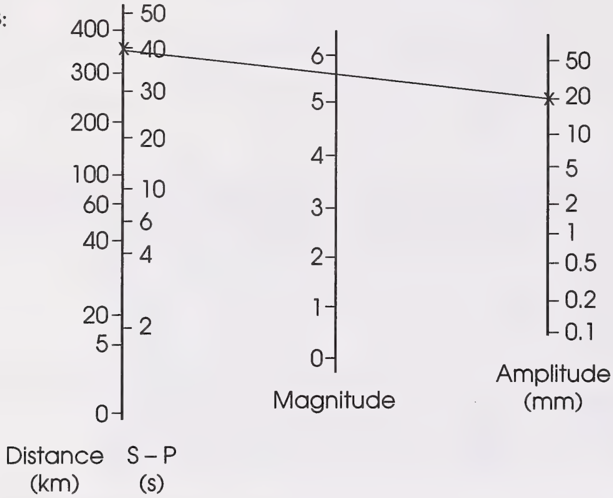
Wave	Ground Motion
P-wave	When the P-waves hit the house, it will move from side to side.
S-wave	When the S-waves hit the house, it will move up and down.

6. Step 1: The P-waves arrived at 0 s, and the S-waves arrived at 40 s.



Step 2: $S - P = 40\ s - 0\ s$
$= 40\ s$

Step 3:

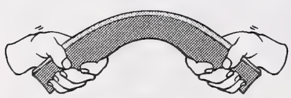
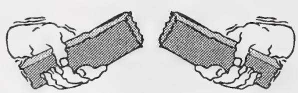
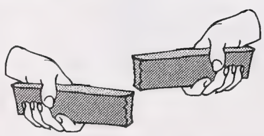


Step 4: The magnitude is about 5.5.

7. **Textbook question 2:** Answers may vary. Your answer should include the following:

- Earthquake prediction would cut down on loss of life and injury because people could leave the area or prepare for the earthquake.
- Earthquake prediction would reduce loss or damage to property because people could prepare.

8.

Elastic Rebound of Wood	Earthquake Correlation
	Geothermal forces cause rock layers to bend.
	Rock layers are bent until they reach their elastic limit.
	When more stress is placed on the rock layers, they break sending out vibrations.
	The rock layers will rebound to their original horizontal layering.

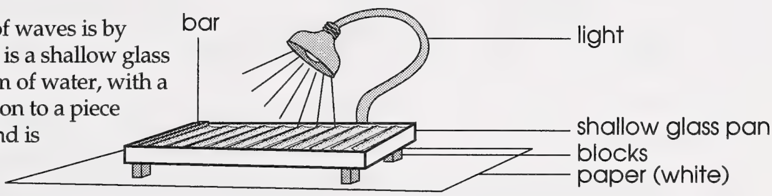
9.

Wave	Characteristics
P-waves	• fast waves, travel through interior including core • particles of matter move parallel to direction of wave
S-waves	• slower than P-waves, cannot pass through the core • particles of matter move perpendicular to direction of wave
L-waves	• travel along the Earth's surface, not through the interior • cause side-to-side and up-and-down motion • L-waves take longer to pass over the Earth than P-waves or S-waves take to pass through the interior.

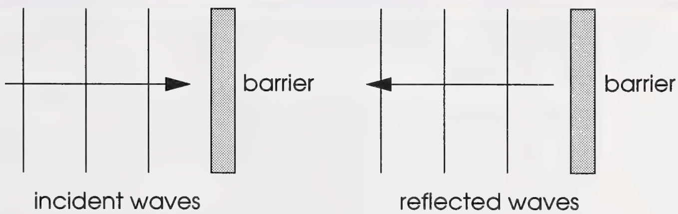
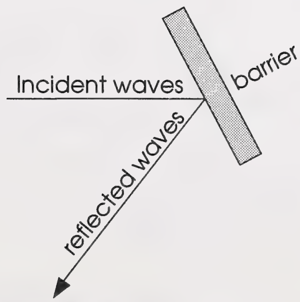
10. Factors to consider in earthquake-resistant construction are what materials to use and how large the building can be and still be safe. They must also consider what type of soil it will be built on.

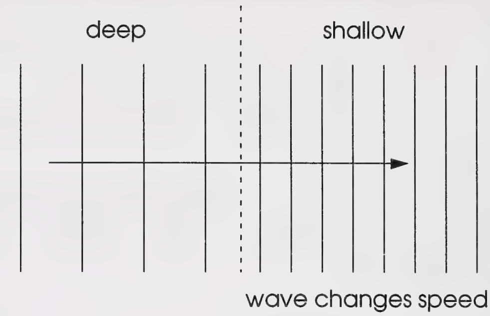
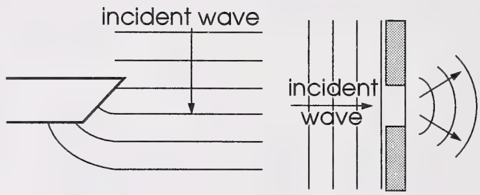
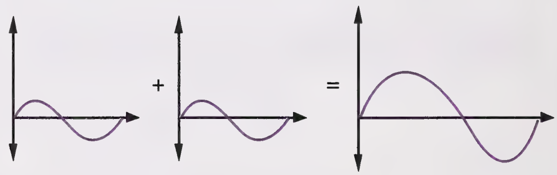
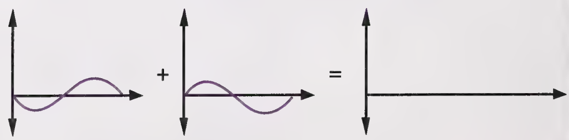
Enrichment

1. One way to study the behaviour of waves is by using a ripple tank. A ripple tank is a shallow glass tub containing approximately 2 cm of water, with a lamp above which casts shadows on to a piece of paper below it. A bar on one end is used to produce waves. You can check on the use of ripple tanks in most physics books.

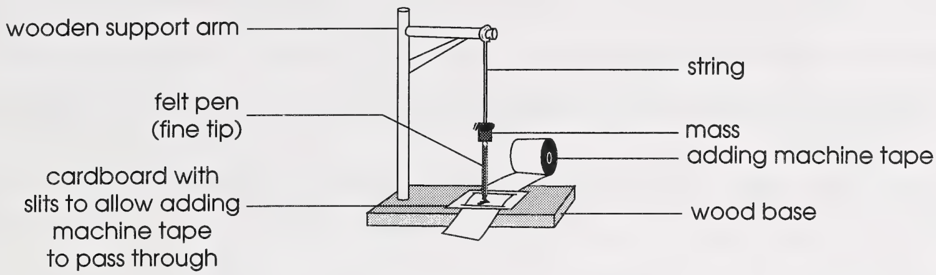


The following are different experiments which may be tried.

Property	Illustration
Reflection • A wave is reflected when it bounces off a barrier. • If a wave encounters a barrier at an angle, the angle at which the wave hits the barrier is equal to the angle at which it is reflected.	

Refraction Refraction is the change a wave makes as it passes from one medium to another. When a water wave travels from deep water to shallow water, its speed and wavelength decreases.	
Diffraction Diffraction (bending) occurs when waves bend around a barrier or spread out after passing through a gap.	
Interference Wave interference occurs when two waves combine with each other. Imagine you are looking at the end of the wave. When the waves have the same frequency and direction, and peak and trough at the same time, their combined amplitude is larger than a single wave. This is called constructive interference. Destructive interference occurs when two waves have peaks and troughs at different times. The amplitude of the resultant wave is smaller than that of the waves before they met. If the waves are exactly opposite in peak and trough they cancel each other. In a ripple tank constructive interference causes patches of light, and destructive interference produce patches of dark. In the ripple tank it is not likely you will get matching waves but some light and dark patches should occur indicating partial interference.	 

2. The following diagram shows one possible design for a seismograph. With this design you have to pull the tape yourself. You may be able to come up with a design in which the tape is pulled slowly by some device.



The following is a sample investigation.

Investigation: Seismograph – Design and Use.

Purpose

Study the relationship between distance from the source of vibrations and the seismic record produced.

Variables

- manipulated
  - distance to source
- responding
  - seismic record
- controlled
  - seismograph used
  - surface the seismograph rested on
  - intensity of vibrations at source
  - speed with which the adding machine tape is pulled

Hypothesis

If we increase the distance to the source of the vibrations, then the seismic record will show a smaller zig zag pattern because the intensity of the waves will decrease.

Procedure

Step 1: Collect a seismic record at measured distances from the source of vibrations.

Step 2: Compare the seismic records produced.

Observations

Record your observations in a chart similar to the one which follows.

Distance from Source	Distance of Seismic Record Produced

Analysis and Interpretation

Your seismic record should verify the hypothesis stated in your lab report.

3. Answers may vary. Some sample questions are given as follows:

   - Where were you and other members of your family when the earthquake struck?
   - How much warning did you have?
   - What went through your mind during those moments when you first realized you were experiencing an earthquake?
   - What did you and other members of your family do to save yourselves?
   - Do you have any pets? How did they react?
   - How long did the earthquake last?
   - How long did it seem to last?
   - Describe the kind of destruction you observed once the earthquake had passed.
   - Describe your feelings immediately following the earthquake. What were the first things you thought you should do?
   - In your opinion, was your community prepared for this emergency?
   - How has this experience affected the way you feel about your home?
   - How will your life change as a result of this experience?
   - Would you like to move to a safer area?
   - How might you change your home and/or community to be more earthquake-resistant?

4. a. Rescue workers were advising people to go home and secure their residences, make sure gas is off, store water, and prepare for aftershocks and three days of no services.

   b. The Marina district was built on rubble (from a previous earthquake), mud, and sand. During the earthquake this area suffered from ground liquifaction which multiplied the effects of the ground motion and therefore the destruction.

   c. Geologists need to gather data regarding ground motion and degree of destruction. This data gathering takes time. The repair crews are interested in undoing what the earthquake has done as quickly as possible – so that normal services can be restored. The reconstruction destroys the information geologists need.

   d. People can limit the impact of earthquakes by doing the following:

      - choosing construction sites with care
      - designing earthquake-resistant buildings
      - retrofitting or tearing down old, unsafe structures
      - storing emergency supplies at home, work, and in the car
      - coordinating emergency procedures with family and community

Section 2: Activity 1

1. Answers may vary. A couple of examples are as follows:

    - Zeus and his thunderbolts indicate an awareness of the relationship between weather and erosion.

    - The giants underground, straining to break free, represent an awareness of forces below the Earth's crust that can reshape its surface.

2. Alfred Wegener theorized that all continents were once joined as one large land mass, which broke apart about 200 million years ago. He further theorized that the pieces then started drifting apart and are still drifting.

3. Answers may vary. If you try to fit the continents together, you will find that they will fit together as though they were once joined.

4. Yes, Africa and the Americas show a close fit, as well as Greenland and Europe.

5. Yes, from southwest Africa to the east coast of South America.

6. Zones of ancient mountains suggest a close relationship between the east coast of North America and the west coast of Africa as well as between the east coast of Greenland and northern Europe.

7. Yes, some areas overlap. The tail end of North America overlaps South America. Britain also overlaps parts of Greenland.

8. The continental shelf is more permanent. The shoreline is always changing due to erosion and deposition. So it is more likely that the continental shelf more closely resembles the shape of the land masses long ago.

9. The areas that now overlap when the continents are moved together probably developed after the land masses started drifting apart. Some may have developed through volcanic activity, while others may have been added by accretion or deposition.

10.

Evidence	Explanation
shapes of continents	The continental shelves of some continents seem to fit together like pieces of a puzzle. It indicates that they may at one time have been joined.
glaciation	Glacial scratches on ancient rock show in which direction the glacier was moving. When the continents of Africa and South America are pushed together, the glacial scratches flow from Africa across to South America indicating that they may have been joined.
ancient mountains	Zones of ancient mountains along eastern North America and western Africa show a close relationship as do those of eastern Greenland and northern Europe. This indicates that these land masses may have been joined at some time.
age of rock making up continental foundations	Ancient bedrock of South America and Africa show a close relationship in composition and age (partially determined by fossil evidence).

11. The evidence presented by this activity appears to confirm the hypothesis that these continents were joined at some time in the past.

12. a. Mountains were thought to form because the Earth was cooling and contracting which wrinkled the crust (much like the skin of a balloon becomes bumpy when some air is let out). The wrinkles on the crust became the mountains.

    b. It was theorized that land bridges once existed connecting one continent to another.

13. Wegener doubted this theory because it failed to explain some things such as the following:

    - the fit of continental coastlines now separated by oceans
    - why mountains are not spread out evenly over the Earth's surface

14. Wegener's theory was not readily accepted because scientists said that the mountains could not have been formed by folding when the continents moved through a weak oceanic crust. Also, he was unable to explain what made the continents move and because it was totally different from the accepted theories of his time.

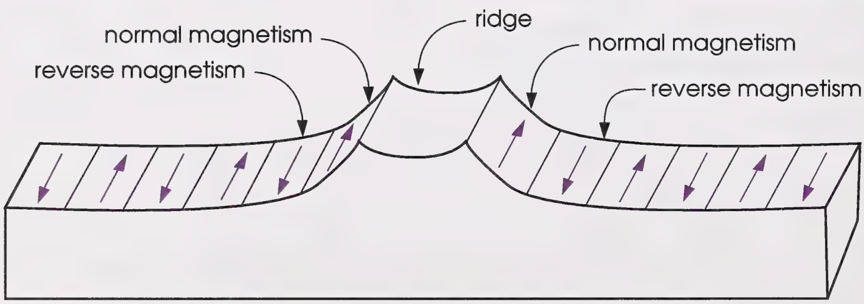
15. The discovery of oceanic ridges lead to the development of the theory of ocean floor spreading.

16. The technology that lead to the discovery of the oceanic ridges were sonar depth finders. The societal issue was World War II which prompted society to try to map the ocean floor. The maps were needed to help navigate submarines. The maps and sonar also helped locate enemy submarines.

17. Paleomagnetic scientists predicted that as molten rock flowed out of the ocean ridges, tiny grains of magnetic rock would align themselves with Earth's magnetic field. This alignment became permanent as the rock solidified. Since the Earth's magnetic field has reversed several times in the past, the ocean floor should show bands of rock with their magnetic alignment first in one direction then the other corresponding to periods of magnetic reversal.

18. This prediction was tested by towing magnetometers across the ocean floor.

19. The magnetometer data showed a symmetrical pattern of normal and reverse magnetized rock bands along both sides of oceanic ridges.



20. The symmetrical pattern which became evident from the magnetometer data gave evidence that the Earth's oceanic crust was spreading at the oceanic ridges. This proved that the continents were once much closer together and are still moving apart. This supported Wegener's theory of a supercontinent.

21. Tuzo Wilson dated the stripes of magnetized rock, determined their rate of spreading, and calculated that a supercontinent could have existed about 200 million years ago just as Wegener had suggested.

22. The theory of plate tectonics states that the Earth's lithosphere is broken into segments called plates, which slide over the hot, thick asthenosphere.

23. Wegener's theory of continental drift had only the continents moving and breaking through the solid oceanic crust. The theory of plate tectonics has both continental and oceanic crust sliding over the molten asthenosphere.

Section 2: Activity 2

1. Answers may vary. The most convincing piece of evidence is the data gathered by dragging the magnetometers across the ocean floor. Scientists predicted that if the ocean floor was spreading, the magnetic rock in the lava should align themselves with the magnetic field. These magnetic alignments should reverse each time the Earth's magnetic field reversed. When scientists tested this theory by dragging a magnetometer across the ocean floor, they found that the direction of the magnetic alignment alternated on both sides of the ridge. This was exactly what they predicted.

2. For the first student's hypothesis, the asthenosphere is not like water. It more closely resembles a soft plastic. The plates are attached to this plastic layer – they do not float like leaves on a pond. The huge plates of the lithosphere are much too massive to be moved about by air.

   For the second student's hypothesis, the air of the atmosphere and the water of the hydrosphere are both fluids. This means that molecules can flow past each other – they are not locked into a specific arrangement in relation to each other as are molecules of a solid like the lithosphere. Because the molecules of fluids are free to move when fluids are heated unevenly, convection currents develop which redistribute the thermal energy. This happens in both the atmosphere and hydrosphere as the sun heats the Earth's surface unevenly. This does not happen to the lithosphere because convection currents do not exist in a solid.

3. Answers may vary. Since the Earth's interior is not all solid and varies in temperature, convection currents form in the mantle and move the plates about.

4.

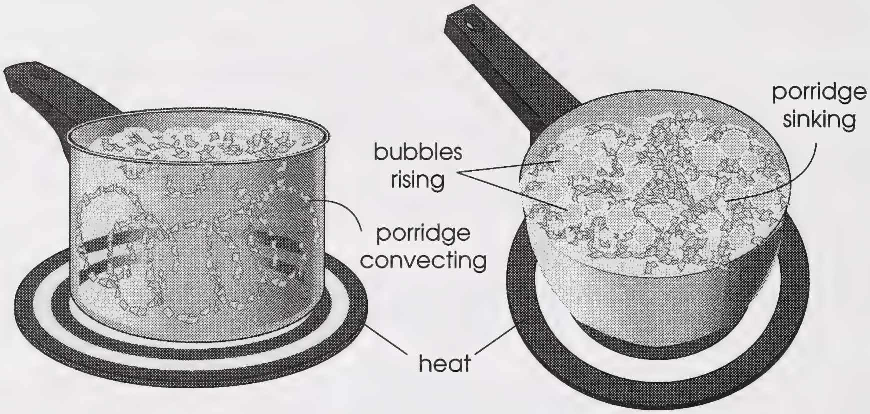
Depth (km)	Layer	Description
0 – 100	lithosphere	• cool • solid • brittle relative to asthenosphere
100 – 250	asthenosphere (part of upper mantle)	• hot • soft • plastic-like
250 – 600	mesosphere (part of upper mantle)	• hotter and stiffer than the asthenosphere • high pressure
600 – 2900	lower mantle	• hotter and denser than the mesosphere due to high pressure
2900 – 5100	outer core	• molten due to extremely high temperature
5100 – 6300	inner core	• highest temperature but solid because of extreme pressure

5. Arthur Holmes believed that radioactive decay generated heat in the Earth's interior.

6. Convection currents are thought to exist in the mantle because of the following:

   - The mantle is a fluid (a thick, soft, plastic-like fluid).
   - The mantle is heated unevenly (the lower parts being much hotter than those parts closer to the surface)

7. From the side of the pot, the porridge is rising and falling in a series of circular motions. The thick cooking porridge is observed to be rising with bubbles in parts of the pot and sinking in other parts of the pot.



8. Yes, the circular motions should be similar for any fluid.

9. The Earth's magma should be rising and falling in circular motions.

10. The part of the Earth that is known as the crust is actually the cool, solid, upper part of the area called the mantle. They are not two separate shells, but are joined. The convection currents in the fluid part of the mantle drag the solid crust along.

11. a. Plate A is called oceanic crust. Its characteristics are as follows:

   - solid
   - brittle
   - density $= 3.0 \times 10^3$ kg/m^3
   - thickness $\doteq$ 7 km

    b. Plate B is continental. Its characteristics are as follows:

   - solid
   - brittle
   - density $= 2.7 \times 10^3$ kg/m^3
   - thickness $\doteq$ 30 km to 50 km

12. a. Plates A and B are converging (colliding). Plate A is subducting (moving under) plate B.

    b. Plates B and C are diverging (moving apart).

13. Plate A represents oceanic crustal material, which makes it more dense than the continental crust represented by plate B. The more dense material will sink below the less dense.

Section 2: Activity 3

1. a. Most earthquakes occur at boundaries between plates especially in subduction zones such as the west coast of South America.

   b. Like earthquakes, volcanic activity seems to occur at plate boundaries especially around the rim of the Pacific plate.

   c. The world's major mountain belts occur along the edges of continents where plates are colliding. For example, the west coasts of North America and South America.

2. Answers may vary.

   - Why do most earthquakes occur along plate boundaries?
   - Why is there so much volcanic activity along plate boundaries?
   - How can you explain the location of the world's major mountain belts along plate boundaries?

3. Answers may vary.

   - Earthquakes are the result of movement in the Earth's crust. Since there is movement at the plate boundaries you can hypothesize that the plate boundaries is where earthquakes will occur.

   - Volcanic activity results when magma rises to the surface. You can hypothesize that volcanic activity will occur along the plate boundaries since this is where there is movement and cracks in the crust.

   - If the plates are pushing one against the other it is probable that there will be folding of the plates along the boundary.

4. a. The movement of tectonic plates causes potential energy to build up in rock layers. When the rock layers are stressed beyond their elastic limit, this potential energy is converted to kinetic energy in the form of earthquakes.

   b. Volcanic activity occurs where magma rises to the Earth's surface. The boundary between two diverging plates becomes a rift in the Earth's oceanic crust. Magma rises through this rift. When oceanic and continental plates meet, the more dense oceanic plate dives under the continental plate. This causes earthquakes and generates enough heat to allow magma to melt through the overlying plate and form chains of volcanoes.

   c. Mountains form along the ocean floor where magma is rising to the surface. Mountains also form where two plates collide. For example, when two continental plates meet, or where oceanic and continental plates meet, the more dense plate flows under the less dense plate, thrusting up plateaus and folding rock layers into mountain ranges.

   d. Island arcs are thought to occur because magma burns through the Earth's crust at plate margins. As the plate keeps moving over the hot spot of rising magma, new volcanoes are formed until eventually an island arc like the Hawaiian islands is formed.

5. Answers may vary. The theory could be rated at 5. It is extremely successful because it seems to be able to explain such a large variety of geological phenomena.

6. Check your labelling with the labelling on Plate 1.4 on page P-2 of *Visions 2*.

7. Three types of plate boundaries found off the west coast of Canada are rift zones, subduction zones, and strike-slip zones. At the rift zones, plates are diverging. At these points, new oceanic crust is being created. In the subduction zones, plates are converging. At these points the more dense oceanic crust is diving under the continental crust. In the strike-slip zones, plates are grinding past each other, moving in opposite directions.

8. The major plates are the Pacific plate, the North America plate, the Explorer plate, and the Juan de Fuca plate. The Pacific and North America plates are sliding past each other in opposite directions. Both the Explorer plate and the Juan de Fuca plate are colliding with the North America plate and flowing under it.

9. Areas in western Canada thought to lie in an active earthquake zone include Vancouver Island, the Queen Charlotte Islands and southern Yukon. These areas are more active because they lie near the boundaries of moving tectonic plates.

10. Answers may vary. The stress generated by plate movement may spread over a wide area of a plate and trigger earthquakes along old faults.

11. The purpose of this investigation is to apply the theory of plate tectonics to the geology of the west coast of Canada.

12. **Textbook question 1:** The major geological feature on the west coast that can be explained using plate tectonics is the coastal mountains. The mountains formed by compression as the plates collided.

    Textbook question 2: If motion of the plates continues as indicated on plate 1.4, it is reasonable to hypothesize that mountains will continue to form along the coast, that volcanoes will emerge, and that the continued subduction of one plate under another will generate earthquakes deep within the Earth.

    Textbook question 3: Any continents that have long mountain chains and are known to be areas of volcanic and earthquake activity are likely to be on plate boundaries. These areas could include the Andes along the west coast of South America and the Himilayas bordering India and China.

    Textbook question 5: The closest seismic gap at the base of the Queen Charlotte Islands is about 650 km from Vancouver or Victoria. Smaller centres of population like Prince Rupert, Kitamat, and Ocean Falls are about 200 km from this seismic gap.

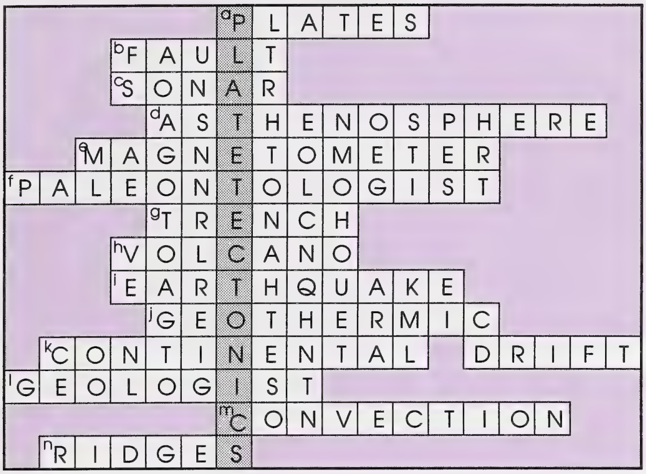
    Textbook question 7: Answers may vary. Human facilities and activities to be avoided in geologically active zones include the following:

    - nuclear plants
    - dams
    - oil refineries
    - bridges
    - gas pipelines
    - highway overpasses

    The following facilities are located in these zones.

    - There is a gas pipeline along the ocean floor between the B.C. mainland and Vancouver Island.
    - Dams, bridges, highway overpasses also exist in this area.

13. The solution to the puzzle is as follows:



The mystery term is **PLATE TECTONICS**.

Section 2: Follow-up Activities

Extra Help

1. The following is a collection of data Alfred Wegener used to help support his theory of **continental drift**.

   Oceanic ridges discovered by sonar gave rise to the theory of **ocean floor spreading**. The striped pattern of normal and reverse magnetism imprinted in the rocks on both sides of oceanic ridges prompted scientists to conclude that the oceanic crust is **spreading** at oceanic ridges. According to the theory of **plate tectonics**, the Earth's lithosphere is broken into **tectonic plates**. Scientists theorize that these plates slide over the **asthenosphere** driven by **convection** currents. **Geothermal** energy causes a difference in density of the materials that make up Earth. Rising **magma** and subducting **plates** result in diverse geological phenomena at plate boundaries.

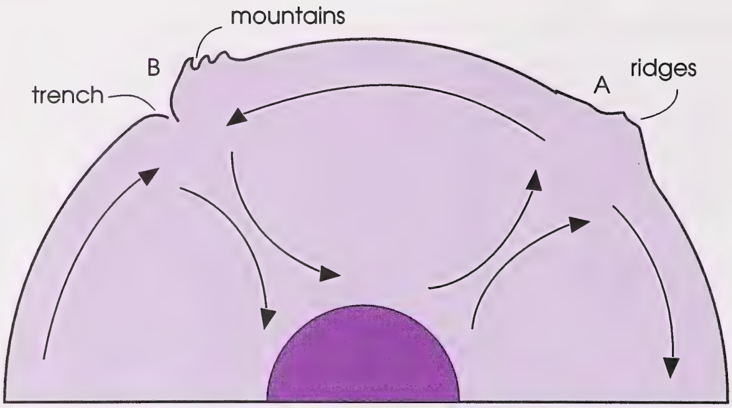
2. **Textbook question 1:** Answers may vary. They may include the following:

   - motion of continents
   - mountain ranges at plate boundaries
   - ocean ridges and trenches
   - magnetic reversal
   - earthquake and volcanic activity at plate boundaries
   - age of rock decreases as ocean ridges are approached

   a. **Textbook question 2:** The process suspected of providing the energy to move the tectonic plates are convection currents in the asthenosphere. This type of thermal transfer occurs in this layer of the Earth because it is a fluid and heated unevenly.

   b. The character in the cartoon is referring to what happens at ocean trenches and ridges due to the convection currents in the asthenosphere. New crustal material is continually made at the ridges as the rising magma reaches the surface, cools, and solidifies. This material slides along the Earth's surface and is eventually pulled back down into the Earth's interior at subduction zones. This material becomes hotter as it is pulled down and melts to become part of the fluid asthenosphere.

4.



At A, where magma is rising to the surface, oceanic ridges are created. At B, where crustal material subducts, oceanic trenches are created. Subduction can set off earthquakes, and magma melts through the overlying plate, forming chains of volcanoes.

5. **Textbook question 3:** Three different types of plate margins are found off the west coast, near Vancouver. There is a large oceanic to continental plate subduction zone. This gives rise to both earthquake and volcanic activity. The Juan de Fuca ridge is a diverging zone where new crust is formed. The Queen Charlotte fault marks the boundary between plates that are grinding past each other and as such may be the site of future large earthquakes.

Enrichment

1. Answers may vary. Some examples that should be in your paragraph are given.

Support

- Resisting Wegener's initial theory was good science because
  - they already had a theory that was able to explain some of the geological phenomena observed (for example, mountains resulting when the Earth cools and shrinks)
  - Wegener's theory would mean the solid continents needed to break through solid ocean crust to move
- Scientists should not except new theories until they are a better explanation of observed phenomena than the old theories were.

Dispute

- Wegener's evidence was overwhelming and scientists should have believed in his theory. Some examples are as follows:
  - fossil evidence
  - fit of continental shelfs
  - fit of mountain ranges on different continents
  - paleomagnetism
- Scientists feared that they would lose credibility if they appeared to change their minds.
- They clung to their old theory not because it was better, but because it was established.

a. Scientists theorize that the Earth was born from a vast rotating cloud of hot gas and dust. This material they believe was a remanent of explosions of distant supernovae. As this material collided and clumped, the Earth (as well as the rest of the solar system) grew.

b. The collisions generated an enormous amount of heat. The Earth was hot when it was new about 4.5 billion years ago. Although the Earth has cooled since then, radioactive decay continues to add more heat in the Earth's interior.

c. When the temperature of the Earth was high enough to melt iron, the layering of the Earth's interior began as heavy elements fell, and lighter elements rose.

a. The three types of plate merging occurring at plate boundaries are as follows:

   - ocean/ocean – the Marianna Trench in the mid-Atlantic ocean.
   - ocean/continent – the Andes Mountains along the west coast of South America.
   - continent/continent – the Himilayas where the continent of India is trusting under Asia.

b. There is a large amount of heat in the interior of the Earth which tends to move towards the cooler, outer surface from the hot core.

c. Mantle convection is believed to be separated into two layers. An upper set of convection cells is driven by a lower set of convection cells.

d. Earthquakes can be traced to a certain depth only. It is believed the crust subducts only to this level.

e. Analysis of the large scale photographs shows that the Earth is a very bumpy object. Regions where the mantle is convecting up show swells while regions where the mantle is convecting down show depressions.

f. A special type of convection which occurs under the middle of the plates is called plumes. Plumes are stationary upward convections of the mantle. These plumes create hot spots in the crust where the mantle either breaks through or comes close to the surface of the crust. Two examples are the islands of Hawaii and the geysers in Yellowstone National Park.

ection 3: Activity 1

It was difficult to persuade early scientists that huge glaciers had much to do with sculpting the Earth's surface because glaciers did not exist in most places. Scientists had nothing to serve as models.

Louis Agassiz's studies led him to believe that the valley glaciers were remnant of great icecaps that covered much of Europe and North America during an ice age.

Scientists theorized that these large rocks were deposited by glaciers because their composition is different from the composition of the rock material they rest on. Glaciers are the only way these massive rocks could have been transported – they are too heavy to have been carried by wind or water.

4. The grains of sand on the sandpaper can be used to smooth and polish wooden surfaces. The rock material imbedded in the glacial ice smooths and polishes the surface of the Earth in a similar manner as the glacier moves across the land.

5. The analogy is accurate in that both the conveyer belt and the glacier move material to the front and in one direction. However, the conveyer belt moves material along the top while a glacier tends to push the material in front of it.

6. A glacier is a long-lasting mass of ice formed by the compaction and recrystallization of snow which flows downhill.

7. The two major type of glaciers are as follows:

   - alpine glaciers – glaciers that form in mountainous areas
   - continental glacier – ice sheets that cover polar regions

8. Snow can accumulate and glaciers can form in low latitude areas (areas toward the equator) at high altitude because temperatures at the high altitudes are low enough so melting does not occur.

9. The force of gravity makes continental glaciers flow outward to areas of thinner ice accumulation.

10. The motion of a glacier can be shown using time lapse photography. You could also mark the ice surface in some way in relation to the adjacent land to track the glacial motion.

11. All of the glacier does not move at the same speed. The bottom appears to move more slowly.

12. One reason that the bottom of the glacier moves more slowly than other parts of it may be the friction it has to overcome as it moves across the rough terrain.

13. a. serrated linear crests
    b. cirque
    c. U-shaped valley
    d. evidence of smoothing
    e. striations

14. a. lateral moraine
    b. end moraine
    c. medial moraine

15. The glacier in the diagram is retreating. The series of small moraines formed at the front of the glacier indicate that the ice is dropping back leaving the end moraine deposits.

16. Moraines are made up of unsorted rock material. Moraine components vary from soil particles to large boulders.

17. Outwash plains are formed by the deposition of fine rock materials transported by glacial meltwater.

18. Scientists came to this conclusion by studying the glacial deposits. The Laurentide Ice Sheet, because it originated on the Canadian Shield, left igneous and metamorphic rock deposits. The Cordilleran Ice Sheet brought limestones and sandstones. The mixture of these different rock deposits in Alberta indicates the boundary between the two glaciers.

19. Some geological features created by glaciers are as follows:

    - levelled land which forms Alberta's prairie region
    - groups of low rounded hills made up of glacial moraine formed when glacial ice stagnated and left deposits
    - large river valleys showing that they once contained far larger rivers, during glacial runoff

20. The fertile soil that covers the prairies was deposited by glaciers, glacial lakes, and glacial runoff. Many of the gravel and sand deposits mined in Alberta were deposited by glaciers.

21. Glacial meltwater is responsible for many large river channels. Canada's rivers once drained to the north. When the glaciers that covered Canada began to melt, parts of the continent began to uplift because the mass of the glacier was removed. This uplift caused the rivers to flow south. The melting glacier created much meltwater which carved drainage channels. Many of these channels became our present river system.

Section 3: Activity 2

1. Cold air is more dense and will therefore flow out and down, displacing the lighter, warm air.

2. Diagram A is correct because the cold air, which is more dense, moves down from the glacier.

3. The air over the glacier is colder and therefore more dense than the air over the adjacent land. This creates a high pressure area which causes cold air to move off the glacial ice and cool the climate of the land areas next to the glacier.

4. The term ice age refers to a time when glaciers covered much of the land mass and cooled the temperature of a large area.

5. Scientists believe they have found evidence for at least five periods of glaciation.

6. The present interglacial period is believed to have begun about 10 000 years ago.

7. a. The land formations showed different layers of polished and striated rock covered by glacial deposits which indicated several different periods of glaciation.

   b. The ratio of heavy isotopes of oxygen to ordinary oxygen in the shells of fossils depends on the water temperature at the time the shellfish lived. Fossil shells from different layers of sediment show a warming and cooling of the sea which supports the theory of repeated glaciation (ice ages).

   c. Scientists have used radioactivity to date past sea level changes. Drops in sea level corresponded to periods of glaciation. The buildup of ice during the ice ages lowered the sea level and when the glaciers melted, sea levels rose.

8. Sea levels would rise as much as 70 m if all present glacial ice melted. The effect would be that many coastal areas would be flooded. Much of the world's high population areas are along the coast. In addition, the effects of hurricanes and monsoons would be far more damaging further inland.

9. The contributions of each scientist are as follows:

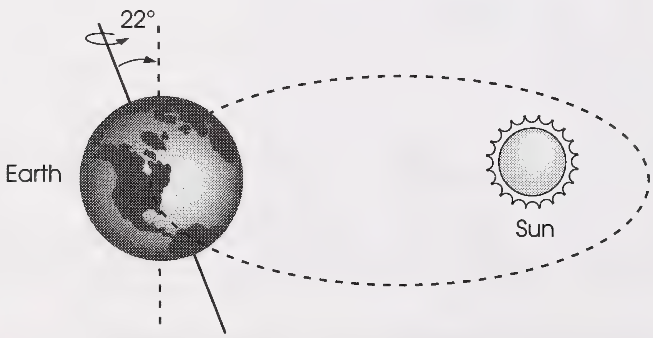
   - Alphonse Adhémar proposed the theory that the Earth enters an ice age whenever either hemisphere enters the winter season while it is at its farthest point from the sun.
   - Johann Kepler demonstrated that the Earth's orbit around the sun is an ellipse, not a circle, which illustrated that the Earth is at times closer to the sun than at other times.
   - James Croll explained how an accumulation of snow and ice on the Earth's surface would absorb less sunlight, further cooling the planet's surface and air above it thereby intensifying the ice age.
   - Milutin Milankovitch published a theory that explained the occurrence of ice ages on three changes in the geometry of Earth's orbit.
     - orbit's eliptical shape
     - variations in the Earth's tilt
     - wobble in the Earth's axis of rotation

10. In a positive feedback system, the product of an action increases that action. The idea proposed by James Croll is an example of such a system because the product of the action, cold temperature and snow accumulation, increases the action. In other words, it leads to colder weather and more snow accumulation.

11. Three variations in the geometry of the Earth's orbit that alter the amount of solar energy received by the Earth are as follows:

    - the shape of the Earth's orbit
    - the variation of the Earth's tilt
    - the wobble in the Earth's axis of rotation

12.



13. CLIMAP was an international project (Climate: Long-range Investigation, Mapping, and Prediction). This study used technologies such as radioactive dating, computers, and ocean floor exploration to show that climate changes did occur regularly at times predicted by Milankovitch's theory, thereby supporting the theory.

14. Answers may vary. It is important to understand what causes glaciers so that future ice ages can be predicted. With increasing populations and the need for increasing food production, it may be more important than ever to be able to predict future climate changes.

Section 3: Activity 3

1. a. The varied life-forms responsible for these oil deposits are evidence of a much warmer, wetter climate in this cold, barren land some time in the past.

   b. The presence of fossilized life-forms that could not survive in the present climate of the area indicate that the climate has changed.

   c. Landforms left by glaciers in now warmer areas devoid of ice indicate that the climate in the area was at one time much colder.

2. The average temperature difference was believed to be 6° C.

3. The natural pace for climate change is measured in **thousands** of years.

The concern is that greenhouse gases are causing a major shift in global climate, at a rate that far exceeds the planets past climate changes.

Answers will vary. One possible statement is as follows:

Is global warming a threat and should action be taken to deter the emissions of greenhouse gases, or are global climate changes for the most part unrelated to greenhouse gas emissions and part of a natural cycle posing no immediate threat?

a. The Earth is surrounded by an atmosphere containing gases such as water vapour and CO_2 that absorb some of the sun's radiation. The sun's energy that is trapped between this envelope of gases and the Earth warms the Earth's surface just enough to sustain life.

b. Artificial pollutants have added to natural gases and have altered the concentrations of some of the energy-absorbing gases. The concern is that this will warm the Earth's surface too much – altering its ability to sustain life.

Four significant greenhouse gases include

- CO_2
- Methane
- CFCs
- Nitrous Oxide

CO_2 exists in greater concentration than all of the other greenhouse gases put together. In addition, the concentration of CO_2 is rising most rapidly.

Natural Sources of CO_2	Artificial Sources of CO_2
• produced by plants and animals as they respire • decaying organic matter • volcanic eruptions • forest and grass fires	• burning of fossil fuels • global deforestation • burning of forests to clear land

CO_2 is naturally removed from the atmosphere by the process of photosynthesis and by absorption by the oceans.

10.

What Is Known About Climate Change	What Is Thought to Be Known About Climate Change
• CO_2 absorbs solar energy. • CO_2 levels in the atmosphere are increasing. • CO_2 is given off when fossil fuels are burned. • CO_2 in the atmosphere is part of a natural cycle. • CO_2 levels in the atmosphere have varied in the past for natural reasons. • When CO_2 levels in the atmosphere increase, the climate warms up.	• The rapid increase in CO_2 levels is caused by process in modern civilization (such as the burning of fossil fuel and deforestation). • Global average temperatures are increasing.

11.

Alternative	Consequences
maintain status quo; do nothing about global warming – let nature take its course	Positive • no altering of lifestyles • industry and government spend less money to reduce greenhouse gas emissions
	Negative • may be ignoring something that could be catastrophic for many parts of the world • may cost a lot of money to fix in the future if it does not fix itself
change lifestyle to cut down on greenhouse gas emissions	Positive • may be safeguarding the world from future catastrophy • cutting back on emissions is environmentally friendly and decreases pollution in general
	Negative • need to alter your lifestyle • will cost money
make no immediate decision, but study the situation further	Positive • will gain a better understanding of climate change • studies may indicate changes in lifestyle are unnecessary
	Negative • research costs money • postponing actions may make it too late to save the planet from the harmful consequences of global warming

12.

Strategy	Examples	Positive and Negative Consequences
Engineering Countermeasures	• spreading dust in the stratosphere to reflect more sunlight • reflect sunlight using satellite mirrors • spread iron into the ocean to stimulate CO_2 uptake by plankton	Positive • global warming could be reduced • no change in lifestyle necessary Negative • expensive • strategies may have unknown side effects
Adaptive Strategies	• revise building codes to adjust to rising sea levels • develop water management strategies • plan for droughts • develop new crop strains	Positive • will alleviate the harmful effects of global warming • no great changes in lifestyle are required Negative • costly • may not be able to alleviate all harmful effects • may be too little, too late
Mitigation Strategies	• using alternate energy sources • conserving energy • reducing other greenhouse gas emissions	Positive • may save the planet from harmful effects of global warming • cut down on pollutants in the environment • save fuel Negative • calls for a change in lifestyle • will affect many jobs

13. Answers will vary. You may decide that the possible consequences of global warming are such that even in the light of uncertainty you will favour the implementation of mitigation strategies and therefore decide to take action.

14. Answers may vary. You may decide to conserve energy as much as possible, join an organization dedicated to preserving the worlds forests, and learn all you can about possible energy alternatives for Alberta.

Section 3: Follow-up Activities

Extra Help

1. a. iii   b. iv   c. ii   d. v   e. i

2. Answers may vary. Some examples are as follows:

   - level prairie land
   - low rounded hills made up of glacial moraine
   - large meltwater runoff channels
   - cover of fertile soil
   - gravel and sand deposits
   - dry couleés of southern Alberta

3. a. Fossil shells contain oxygen. During cooler (glacial) periods of Earth's history, the ratio of ordinary oxygen isotope to heavy oxygen isotope was different from the ratio during warmer (interglacial) periods. The shells from different layers of sediment showed a warming and cooling of the oceans that correlates with the retreat and advance of glaciers.

   b. Scientists could use fossils along shorelines to chart the rise and fall of sea levels. They were able to correlate the falling sea level with times of ice buildup (glacial periods) and the rise in sea level with melting of ice (interglacial periods).

   c. Geologists used radioactive dating of fossil shells to correlate the rise and fall of sea level with the advance and retreat of glaciers.

4. - The Earth is in the part of its orbit that brings it farthest from the sun.
   - The northern hemisphere is tilted at 22° (1.5° less than the present tilt).
   - The Earth is experiencing a wobble in its rotation that could further decrease the amount of solar radiation received by the northern hemisphere.

5. Ice core samples allow scientists to study the composition of ancient atmospheres and allows them to formulate hypotheses about the connection between the concentrations of certain gases in the atmosphere and climate change.

6. The burning of fossil fuel by society is believed to be the main contributor to the rapid rise of CO_2 concentrations in the atmosphere.

7. **Textbook question 10:** Short-term climatic change could be more destructive than long-term climatic change because the short-term change does not give organisms time to adapt to the change. The process of adaptation is a gradual one. Sudden, extreme climate changes would not allow the adaptation process to take place, thus leading to the extinction of species. The process of adaptation will be discussed more in Module 4.

Enrichment

1. a. A drumlin is a streamlined hill shaped like an inverted spoon. It is thought to be formed by ice sheets overriding and reshaping glacial deposits left by earlier glacial advance.

   b. A horn is the shape peak that remains after cirques have cut back into a mountain on several sides.

c. A hanging valley is a smaller valley that terminates abruptly high above a main valley. The glaciers that form main valleys are more massive and have more erosive force than do the smaller tributary glaciers that flow into it. The larger glacier therefore erodes a deeper valley. After the glaciers disappear, the tributary valleys hang high above the main valley.

d. A hummocky moraine consists of a jumble of small hills or mounds separated by irregular depressions. The hummocky moraine is thought to be formed by depositions from disintegrating, stagnant ice. The hills are formed when glacial moraine material is washed into holes or cracks in the stagnant ice. The depressions are formed when buried blocks of ice melt.

e. An esker is a long, stream-shaped ridge of glacial moraine deposited by glacial meltwater as it flowed in tunnels within or under glaciers.

2. Answers may vary. You should state your opinion clearly, then give examples to illustrate why you feel as you do. For example, if you believe that individuals can and should make a difference, you might mention that if everyone acted responsibly on an individual basis, the combined effect would make quite a difference. People can also unite to pursue a common, worthwhile cause.

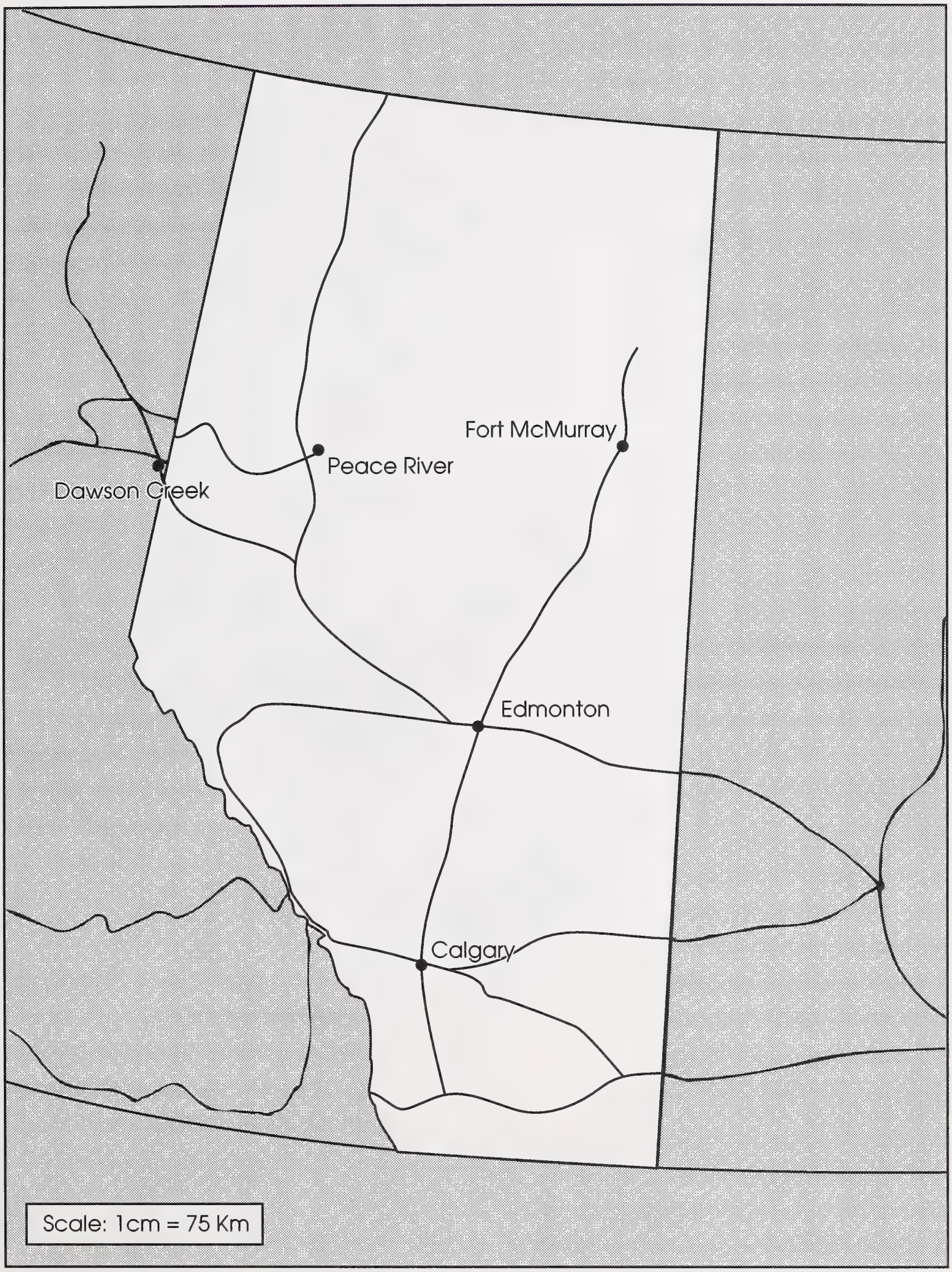
3. a. Lithoprobe is a comprehensive research program to study the interior of the Earth. It is a collaborative effort by scientists from various disciplines including geophsyicists, geologists, and geochemists.

b.

Type of Scientist	Example of an Area of Investigation
geophysicist	• identifying the composition and structure of rock lying under the surface
seismologist	• interpreting seismic data to understand geological structures
geologist	• studying the relative positioning of rock formations to determine their direction and degree of motion
geochemist	• studying rock composition
geochronomist	• determining the time of formation of rock layers

c. Scientists hope to improve the ability of the scientific community to define areas of volcanic and earthquake activity, to expand the understanding of geological processes on a global scale, and to provide a better framework from which mineral, petroleum, and geothermal resources can be explored.

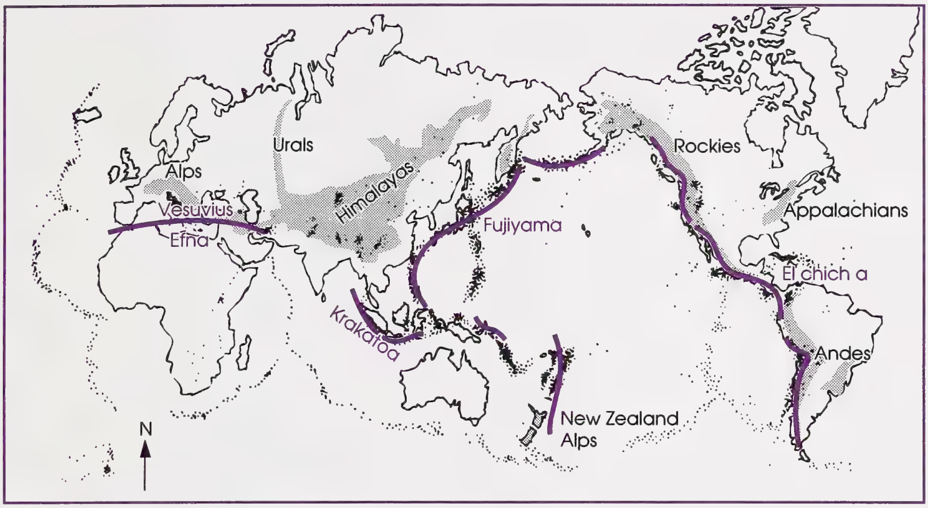
Map Used for Section 1: Activity 3, Question 14 d.

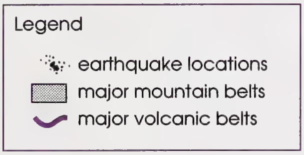


Map Used for Section 2: Activity 1, Investigation: Rejoining the Continents

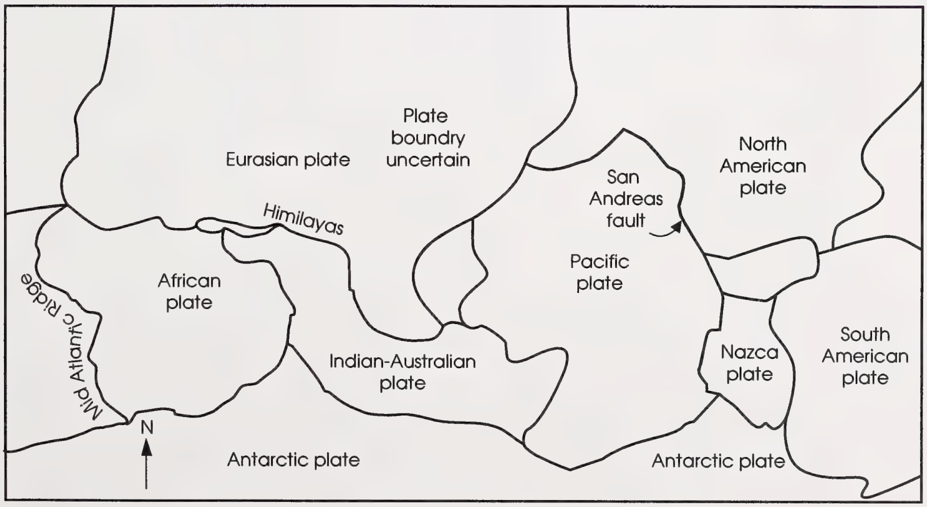
Maps of geological phenomena and tectonic plates used for overlay in Section 2: Activity 3, Questions 1 to 3

Geological Phenomena





Tectonic Plates



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Module 1

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